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J. F. KELLY, Editor

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EDITORIAL

The Recognition of the Engineer As An Executive

By WRAY DUDLEY*

TO the average run of steel mill engineer who has been taking the ups and downs of his work for a decade or more, the arrival of the New Year would normally mean little more to him than tearing the cover from a new calendar. Further marking of the event may be limited to coaxing his mental stamping machine around to the point where it will register twenty-nine rather than twenty-eight and then the New Year floats along like all its predecessors. But on November sixth of last year there occurred an event which can hardly fail to exert in some degree an influence on the activities of many engineers. Without any action on their part they have suddenly been brought to the attention of many folks who ordinarily would hardly give them more than a passing thought. No doubt many of the members of the Association of Iron and Steel Electrical Engineers have given this event and its possible consequences due consideration. But realizing the common failing of many engineers to bury themselves in their work and ignore significant events which occur outside their own activities, the writer feels justified in consuming a little space in this New Year edition to briefly discuss this event and its consequences.

The event which occurred on November sixth will reach its climax on March fourth next when Herbert Hoover is inaugurated the thirty-first President of the United States of America. Thus for the first time in one hundred and forty years the majority of the voters have chosen an engineer as their leader, instead of the lawyer, politician, soldier, statesman. That is to say, they have chosen a man whose natural interests are with things instead of with men or ideas. Not since the days of George Washington has this been done. While Washington was trained as a civil engineer and performed notable pioneer work in that line, he was likewise a planter and soldier before being chosen as President. It was undoubtedly his service as a soldier which won for him the honor of our first President. True, Mr. Hoover is likewise noted for his ability as an organizer of large enterprises as well as a leader of commerce. But his greatest claim to fame undoubtedly rests on his achievements resulting from the exercise of his talents along that line of human endeavor which we broadly classify as engineering.

While there is but little basis for the assumption that his supporters at large gave any particular weight to his engineering talents as such, it is not improbable that it had a very strong subconscious influence on their choice. Aside from the controversial questions of prohibition and religion and other localized issues such as flood control and farm relief, the desire for continued prosperity throughout the Country was doubtless shared in common by practically all his supporters. They must have found reason to believe that the successful engineer was qualified to handle the material affairs of their government with equal success; that the engineer would best know how to encourage and foster those factors which favor industrial activity with its resultant prosperity. Mr. Hoover's unquestioned success in his far flung enterprises as a mining engineer, his demonstrated ability as an organizer of large relief measures and his able handling of the department of commerce for his government, apparently had given a large proportion of the voters a new conception of the public value of a man of native talent and ability when trained as an engineer. They were willing to entrust their welfare to his skill and judgment for four years at least.

Thanks to the radio, the more important issues of the campaign were brought directly to the individual voter in the very words, phrasing, inflection and personality of the candidates. Thus the voter had full opportunity to make his individual choice from first hand information and impressions. On the one hand, he had the magnetic personality of Mr. Smith, skilled in the handling of men and adroit in utilizing their services for purposes of state or party. On the other hand, he had the more prosaic Mr. Hoover, skilled in the handling of material things and directing their economical production and distribution. Thus the two men presented themselves directly to the voters, each of proven ability in his respective field and each appealing to a different type of personality. The tremendous outpouring of votes, exceeding by almost eight million any previous presidential vote, was a convincing demonstration of the people's concern in the affairs of government and those chosen to administer them when once they have been well informed and their interest aroused.

And now what of the result,—how should it be interpreted as indicative of the trend of thought amongst our people. The battle was well fought, long inactive voters came to the polls, many changed from one party to the other, there was abundant activity on both sides, the losers cast fifteen and one-half million votes as compared with twenty-one and one-half million polled by the winner. What caused five out of seven to choose Mr. Hoover? What was the fundamental desire, exerting perhaps a subconscious influence, when the voter marked his ballot? Certainly religion, prohibition, farm relief, flood control Boulder Dam, immigration, foreign affairs, naval policy and a host of other controversial questions all had their effect on various groups of voters. But was there not some other desire held in common by all these, which turned the balance in favor of Mr.

*Electrical Engineer, National Tube Co., Pittsburgh, Pa.

Hoover. The writer believes there was and believes it was based on the ancient urge for food and shelter and clothing and things which caused the **discerning** voter to select Mr. Hoover as the man best qualified by training, ability and experience to assure a continuance of these material blessings under the slogan of "prosperity."

If that was the fundamental thought which actuated the majority of our voters in choosing their leader, it must not be interpreted as an exhibition of wholly materialistic desire on their part. Rather they should be credited with the conviction that with the blessings of material prosperity around them for another four years or more their efforts to solve the other problems which confront various groups of our people would have more assurance of success. In homely words,—"if you want to eat rabbit pie, you must first catch the rabbit," might be said to express their ideas.

Inasmuch as each candidate found means of assuring his listeners that prosperity would continue to flourish under his administration each voter was compelled to exercise his own judgment in selecting the man best qualified by training and experience to carry out that promise. In a rapidly expanding manufacturing country such as the United States, what could be more simple and direct than to choose the engineer for this job, the practical man of industry, the leader of commerce, the man who would naturally be expected to find ways and means of encouraging industrial activity, a man whose entire active life had been concerned in "making grow two blades of grass, where but one grew before." While speaking to the people of the Argentine, Mr. Hoover described himself: "It has been no part of mine to build castles of the future, but rather to measure the experiments, the actions and progress of men through the cold and uninspiring microscope of fact, statistics and performance." Whether the man of politics and the people in the person of Mr. Smith would have been a wiser choice than Mr. Hoover, the man of facts and statistics, only the events of the future will disclose. Nor is it necessary at this time to risk a prophecy, each reader can exercise his own judgment if he so desires.

The administration of a President depends not alone on his own native talent and ability for its success, but perhaps fully as much on the legislation which comes out of Congress and the Senate. These are independent groups, entrusted by their constituents with the exercise of their own free choice and action. They originate measures, the President can only approve or reject. He can talk with them, reason with them, coerce them slightly, but unless convinced that his ideas are best, or that they represent the will of the people, they are not compelled to support him.

Now how will an engineer, a man of facts and science, find ways and means of convincing Congress and Senate, men of politics and law and human affairs, that his recommendations should prevail. We can only conjecture as to what the method will be. But on the basis that there can come out of a man only the ideas and thoughts which are within him, we venture a few suggestions. It will not be surprising if we see in Washington the very unusual spectacle of our next executive attempting to apply to governmental affairs the same system of fact finding and direct approach which he has trained himself to use throughout his life. We may find him cooperating with political friends and foes alike in his efforts to solve the problems which confront him. We may expect him to search for and utilize, brains, ability, and character regardless of political affiliations or geographical location. We may expect an open minded attitude towards political questions and a willingness to set the facts before the people. In a word, we may expect the engineer trained President to freely utilize the talent, ability and judgment of the entire country in his efforts to direct its affairs along the path of peace and prosperity.

If these tactics are followed by Mr. Hoover, they need cause no surprise to engineers for they will only be an elaboration of the methods which they themselves find most useful in their own efforts Such methods may at first disturb those of our public officials and people who are not familiar with them, may cause misunderstanding and opposition for a period, may mean replacement of personnel in some quarters, the re-arrangement of duties or responsibilities in others, in fact may be just as uncomfortable and disturbing as a new and aggressive management taking over the control of an old style steel plant and determined to modernize and increase its production. But if these methods have proven successful when applied to the industrial affairs of small groups of people, there is very good reason for the assumption they will likewise prove successful in the larger affairs of government.

Whatever record is achieved by Mr. Hoover as President, the thinking people of the country will surely endeavor to evaluate the effect of his engineering training on the results. The part played by the engineer in the industrial activity of all sections of the country is becoming more universally known. Each year, he penetrates more deeply into the ranks of the workers and his influence and presence becomes more widely diffused. With the illustrious example of Mr. Hoover sitting in the White House, the public at large would be less than human if it did not turn an inquisitive eye on the engineer with whom it comes in contact. The American public is prone to run to an extreme on any idea which grips its fancy. Should it ever become convinced that engineering methods are being successfully applied to the multitudinous problems which confront Mr. Hoover, the demand for their application in private business affairs will surely follow. If this should occur, the average engineer might find himself imbued by popular fancy with talents far beyond his actual ability and experience. While this might be embarrassing for a time, most any engineer in this organization could be expected to welcome such a condition and make a man size effort to meet the specification. On the other hand, should engineering methods prove to be unsuited to the handling of presidential affairs, the public would most likely as quickly abandon the new fancy and forget its growing interest in engineers. In that improbable event, the pendulum might swing to the other extreme and the engineer might find his efforts and methods discounted and discredited to an extent that would handicap his work. That too would be a very embarrassing situation, but one which we feel will hardly occur. Whether the reaction is favorable or

(Continued on page 74)

Ward-Leonard Control As Applied to Blast Furnace Skip Hoists *

By E. ANDERSON†

IT is not the purpose of the writer to enter into a detailed technical discussion of the Ward Leonard control system, but to present curves and data showing the comparison in operation of a Skip Hoist driven by a squirrel cage induction motor and one driven by direct current motors controlled by the Ward Leonard system.

A.C. DRIVE

The A.C. drive serves a 600 ton Kneeland furnace and consists of a 200 HP 500/83.3 RPM, 3 phase, 25 cycle, 550 volt squirrel cage induction motor of the single stator type having the high and slow speed windings wound in the same slots. The control which is of the magnetically operated primary resistance type consists of line contactor, reversing switches, and low and high speed accelerators.

Figure 1 shows the arrangements of the above mentioned equipment, and Figure 2 shows the control board for the 200 HP motor.

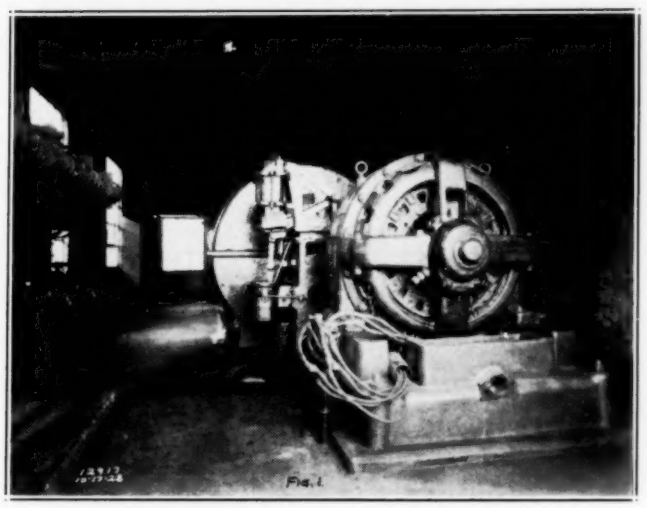

FIG. 1

Figure 3 shows schematically the connections of the primary resistance starter, which functions as follows: In starting from rest the line and direction contactors close energizing both high and slow speed windings which are connected in series with the current limiting resistor. The next step 1st SS and 2nd SS close; this operation connects the slow speed winding to the line through a section of the resistor and short circuits the high speed winding through the balance of the same resistor; 3rd SS follows and full voltage is applied across the slow speed winding. The next step 1st, 2nd, 3rd SS open and 1st HS closes, this removes the short circuit from the high speed winding, allowing same to operate normally in series with a section of the resistor, and short circuits the slow speed winding through the balance of the resistor; 2nd HS and 3rd HS follow in sequence and full voltage is applied to the high speed winding.

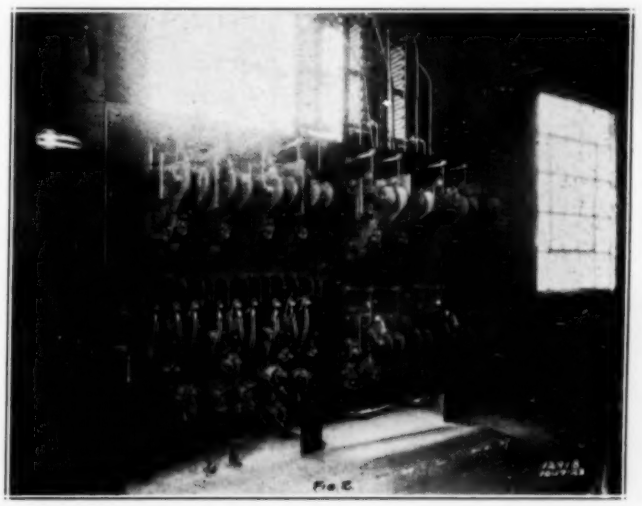

FIG. 2

During deceleration the procedure is reversed, 1st, 2nd, 3rd HS opening and 1st SS, 2nd SS, 3rd SS closing for slow speed, and opening with direction and line contactor for final stop. With this equipment acceleration is controlled by the limit switch only; should the skip car be stopped and started

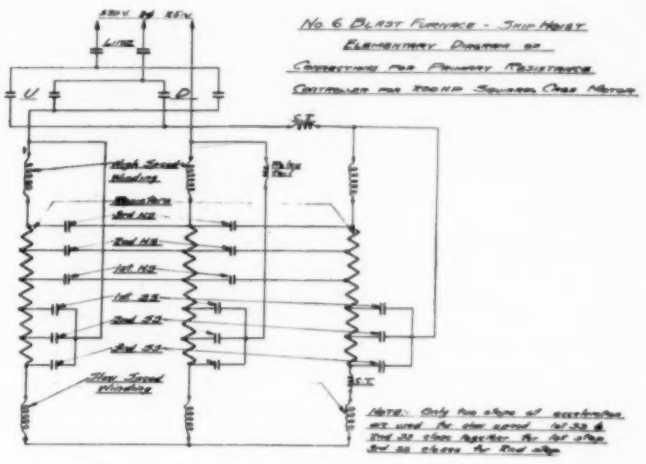

FIG. 3

midway on the skip, the time of acceleration is limited only by the sequence closing of the various contactors.

Graphic curves taken on this equipment are shown by Figure 4. Curves No. 1 and No. 2 show kilowatt input to line when hoisting 9,800 lbs. ore

†Elec. Dept., Bethlehem Steel Co., Sparrows Point, Md.

*Presented before Philadelphia District Section, Association of Iron and Steel Electrical Engineers, November 3, 1928.

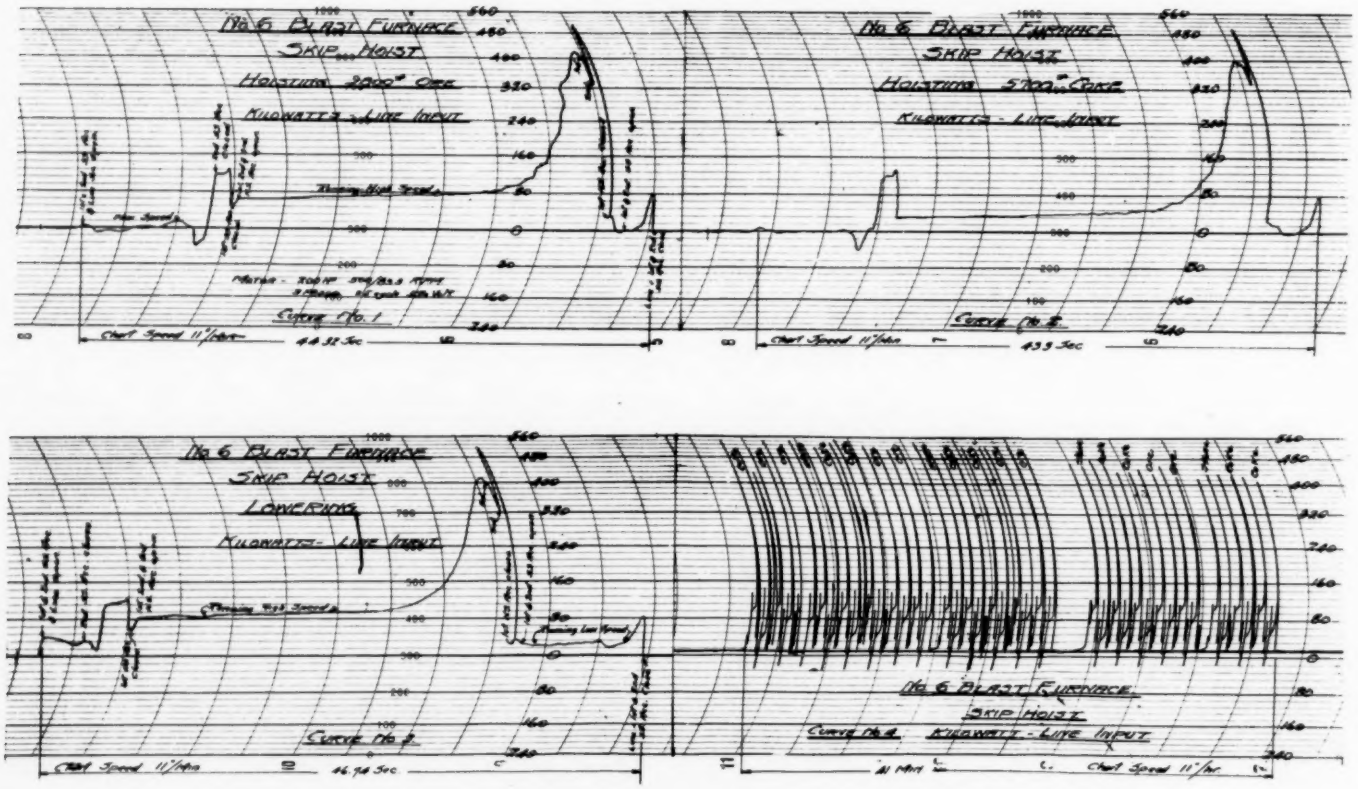

FIG. 4

and 5,700 lbs. coke respectively, while curve No. 3 shows the same data for lowering. These curves are self explanatory. They are marked up showing the various accelerating and decelerating points, time, etc.

Curve No. 4 shows the operation over a period

FIG. 5

of 41 minutes. During this period 8 buckets of ore, 9 buckets of coke and 4 buckets of stone were charged. This constitutes a little more than four charges, each charge consisting of 2 buckets of ore, 2 of coke and 1 of stone.

To further augment—the data shown on curves 1, 2 and 3 following are instantaneous values of current observed for the various points of acceleration while hoisting 9,700 lbs of ore and 6,500 lbs. of coke, respectively.

Contactors	UP Ore	UP Coke	Down
Line-direction 1st SS-2nd SS closed	140	120	160
Running slow speed	80	80	80
1st SS and 2nd SS open	60	55	55
1st HS closes	416	400	400
2nd HS closes	480	448	480
3rd HS closes	527	512	543
Running high speed	90	70	115
1st-2nd-3rd HS open	60	45	55
1st SS Closed	200	180	260
2nd SS Closed	260	300	250
Running slow speed	80	80	80

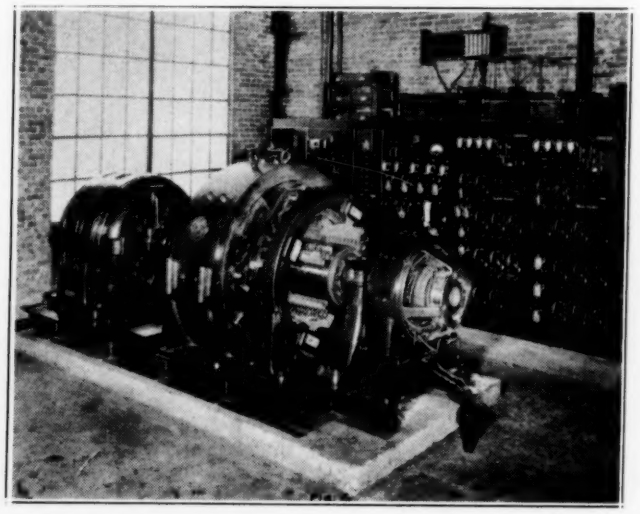

FIG. 6

D. C. DRIVE

The equipment comprising the d.c. drive consists of a 275 HP, 750 RPM, 3 phase, 25 cycle, 550 volt squirrel cage induction motor direct connected to a 165 kw., 500 volt, 750 RPM, d.c. generator and

a 12½ kw. 235 volt, 750 RPM exciter and 2—150 HP, 500/550 RPM, 250 volt d.c. shunt wound mill type motors connected to the hoisting equipment. This apparatus serves a 1,000 ton Kneeland top furnace as shown in Figure 5.

Figure 6 shows the motor generator set and control boards. Starting from the left hand side the first panel mounts an 800 amp. air circuit breaker, the second the primary resistor starter for the squirrel cage motor, 3rd and 4th the panels for controlling the operation of the skip hoist, 5th and 6th the control for the electrically operated Bell and Slide Hoists.

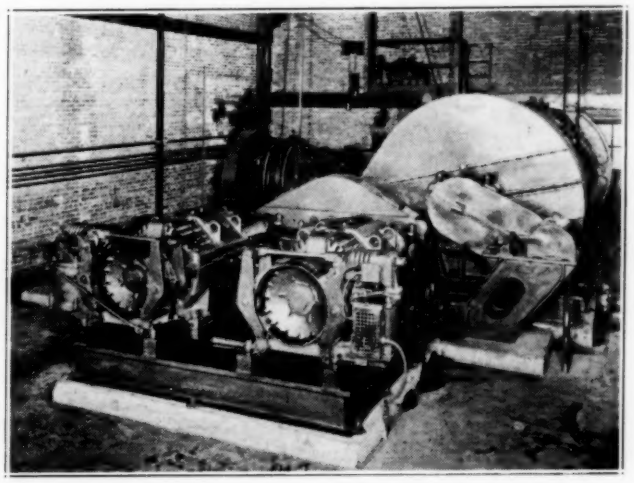

FIG. 7

Figure 7 shows the 2—150 HP d.c. motors connected to the skiphoist; with the bell hoist in the background.

An elementary diagram of connections of the Ward Leonard system as applied to this skip hoist is shown in Figure 8. CB is normally closed, DB is normally open. These two contactors operate only on failure of voltage, operation of slack cable switches, overload or Lilly governor. Contactors U and D are the direction switches and 1A-2A-3A the accelerators. 2AA is effective during periods of deceleration only, FF controls the motor field; this contactor opens immediately after 3A closes and weakens the motor field for—increased speed. N or neutralizing contactor closes after contactors U and D are open and connects the generator field across the generator armature. This connection serves to keep the circulating current through the generator and motor armatures to a minimum value during periods when the skip is idle.

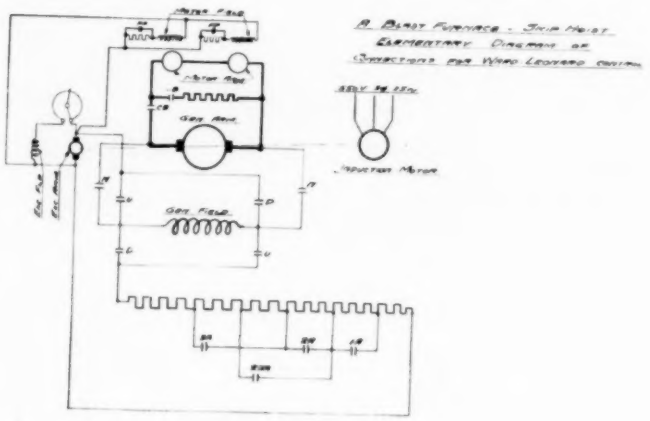

FIG. 8

Graphic curves shown in Figures 9 and 10 show A.C. kilowatt line input and generator d.c. amperes. Curve 5 and 5A cover hoisting 14,100 lbs. ore, 6 and 6A hoisting 7,000 lbs. coke, 7 and 7A lowering the empty bucket and curve No. 8 the operation of the hoist over a period of 38 minutes. During this time 9 buckets of ore, 12 buckets of coke and 4 buckets of stone were charged, constituting approximately 4 charges each consisting of 2 buckets of ore, 3 buckets of coke and 1 of stone.

The following peak values of line a.c. amperes were observed while skip was hoisting 9,200 lbs. ore and 6,800 lbs. coke:

	Up		Down
	Ore	Coke	
Accelerating peak	273	233	150
Running	218	165	45
Pump back on deceleration	75	150	218

Curves made with graphic tachometer and calibrated in feet per minute of skip car travel are shown in Figure 11. Curves Nos. 9 and 10 show variations while hoisting 9,700 lbs ore and lowering empty bucket on a.c. hoist, while curves Nos. 11 and 12 cover the hoisting of 10,400 lbs. of ore and lowering the empty bucket on the d.c. hoist.

Tabulation of comparative data on these two hoists is shown in the following table:

Comparative Data—Blast Furnace Skip Hoists

Data	A.C. Hoist	D.C. Hoist
Capacity of Furnace	600 T	1000 T
Type Top	Kneeland	Kneeland
Length of Skipway	202'-0"	213'-11 7/16"
Vertical Lift	137'-6½"	148'-1¼"
Rating of Motors	1-200 H.P.	2-150 H.P. ea.
Type Control	Primary Resistance	Ward-Leonard
High Speed of Hoist F.P.M.	417	587*
Low Speed of Hoist F.P.M.	69.5	70*
No. of Buckets per Charge	5	6
Weight of Material per Charge	35,100 #	54,700 #
KWH/Ton Material Charged	.637	.554
KWH/Ton Pig Iron Produced	1.74	1.55

*Present setting, but variable to meet new operating conditions

In conclusion, the writer wishes to present items which he interprets as advantages and disadvantages to the two types of equipment.

A. C. DRIVE

Advantages:

1. Lower first cost.
2. Requires less space.
3. No brushes or commutators to maintain.

Disadvantages:

1. Inability to change speed of motor to meet new or increased operation.
2. Heavy control required to handle large values of current.
3. Motors and brakes are of special design which means that spares must be provided for same.

D.C. DRIVE (Ward Leonard Control)

Advantages:

1. Saving in power consumption of 13% on material charged and 10.9% on pig iron produced.
2. Simplicity and lower maintenance of the control equipment.
3. Flexibility. Speed of equipment may be readily changed to suit new conditions.
4. Equipment may be operated directly from the high voltage distribution system.

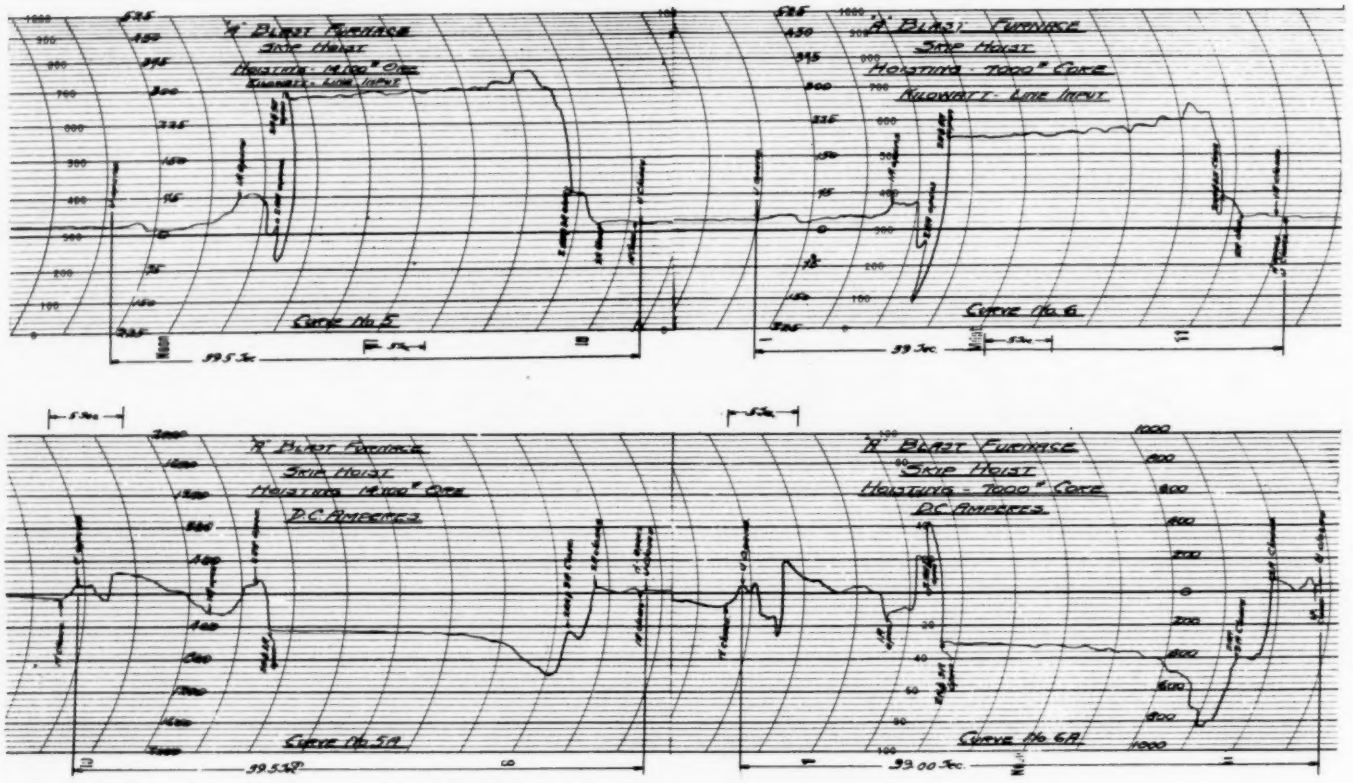

FIG. 9

5. Use of mill type motors and brakes for driving hoist.

Disadvantages:

1. Increased first cost.
2. Space requirement.
3. Brush and commutator maintenance.

DISCUSSION

Walter C. Kennedy*: I might say a word about that paper. I think it is one of the most interesting papers I have ever heard or seen in the way of data and information. I have seen the blast furnace skip hoist control progress now for a number of years, and when we stop to think that the so-called Ward Leonard system (named after Mr. Leonard) has been known for years and never been applied to blast furnace skip hoists, it seems somebody has fallen down on the job. I can remember when we had nothing but a D.C. motor, and with all the contrivances and schemes used it was considered a very difficult problem to control a blast furnace skip. You had a very heavy load of ore, and then a very light load of coke, and then an intermediate limestone load, and used various combinations to operate. They had to stand a very high speed, and when they came to function they had to function at very reduced speed. There were numerous schemes worked up for blast furnace skips, and that particular skip as shown is one of the hardest controls ever made, because the bucket is hung on the top of the car, and when you get up and try to slow down that bucket will start to swing. The hardest point is to slow down nicely.

*Cutler Hammer Mfg. Co., Philadelphia, Pa.

After they had progressed with D.C. control on blast furnace skips we began to hear about the A.C. and everybody got very enthusiastic over the A.C. motors. I might say there was a very big difference brought out in those curves between the functioning of that A.C. motor and the D.C. variable voltage of Ward Leonard control. At first sight you would really believe the k.w. consumption per ton and material is going to be very much higher on that Ward Leonard control, due to the machines you have, and you would assume at first sight the efficiency would be lower, but you can see less k.w hours per ton. I think those curves are a pretty picture to look at and see the results that have been accomplished.

W. B. Shirk†: I wish to compliment Mr. Anderson on the presentation of his paper and on the completeness of the comparative skip hoist data submitted. It has long been my feeling that the solution of the blast furnace skip hoist problem was in the use of variable voltage control even as it proved to be the solution of the slope mine hoist and electric elevator application. It is interesting to note that since the adoption of variable voltage control on these applications rapid strides in their development have been made. There is now being installed in this country a variable voltage mine hoist having a 3200-hp. D.C. driving motor and a full-load hoist speed of 3,000 fpm. There is another mine hoist operating, having control somewhat similar to the variable voltage control schematic shown by Mr. Anderson, which is driven by two 2,000-hp. D.C. motors in series and has a skip speed of 4,050 fpm.

†Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

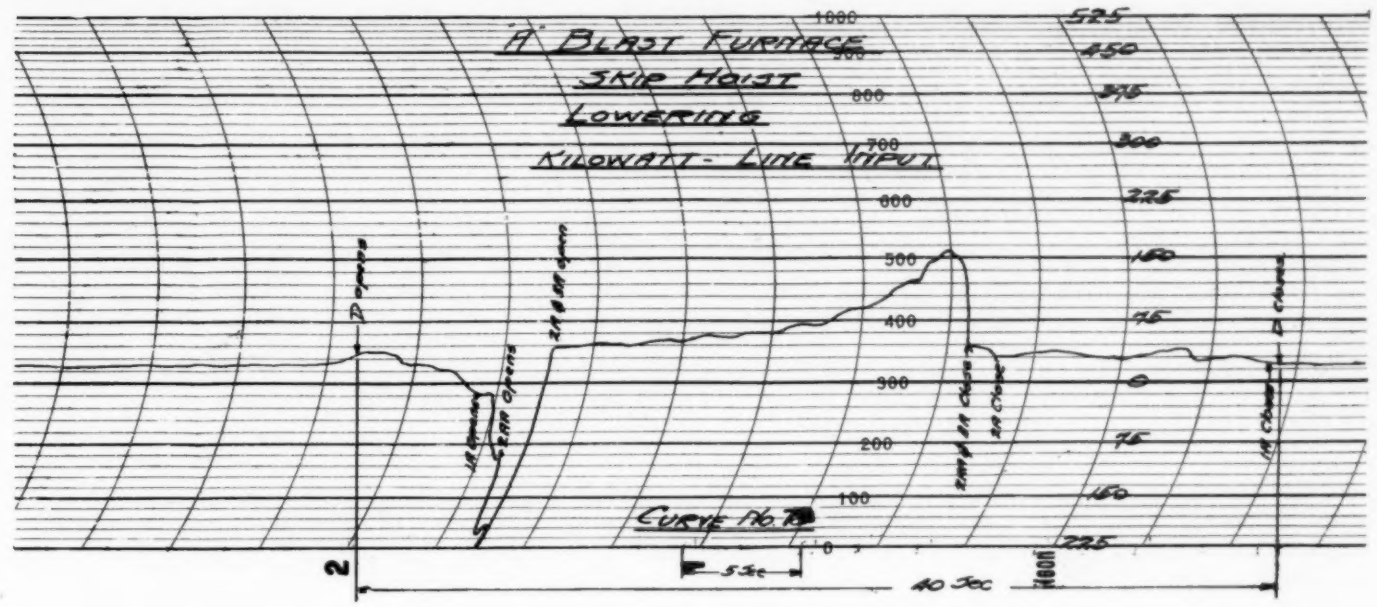
"A" Blast Furnace
Skip Hoist
Lowering
Kilowatt - Line Input
Curve No. 7
40 Sec
Noon
"A" Blast Furnace
Skip Hoist
Lowering
D.C. Amperes
Curve No. 8A
40 Sec
Noon
"A" Blast Furnace - Skip Hoist
Kilowatt - Line Input
Curve No. 8
chart speed 12"/Hr.
38.3 Min
Noon

FIG. 10.

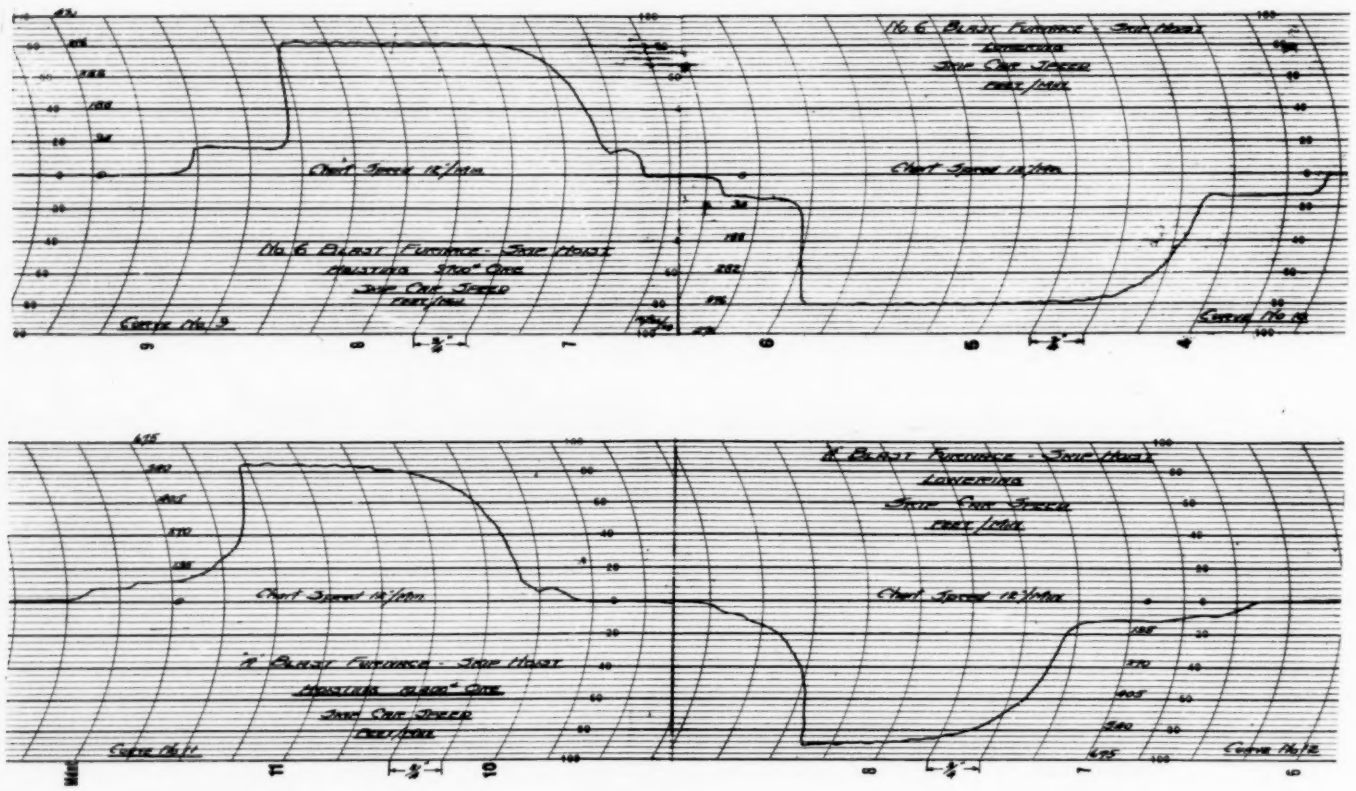

FIG. 11.

Without the use of variable voltage control, installations such as these would have been impossible.

In the absence of variable voltage control on blast furnace skip hoists and actual operating data on the hoists, it was very difficult until these recent installations had been completed, to justify to the user the higher cost of variable voltage control when compared to either D.C. rheostatic control or the A.C. drive, as described by Mr. Anderson. It should be realized in making this comparison that with variable voltage control there is not only included a skip hoist controller but an A.C.-D.C. conversion system as well. Often this eliminates the use of large low-voltage D.C. feeder to the blast furnace and permits the use of high-voltage A.C. lines and high-voltage A.C. motors driving the set. In installations where high power-factor is desirable, synchronous M-G, sets can be satisfactorily applied.

This type of control will assure smooth and definite acceleration and deceleration with resultant elimination of excessive strains and stresses on cables, sheaves, bearings and vibration of structure. Definite descending speeds regardless of load can be obtained whether or not the load is overhauling.

Now that there are several variable voltage skip hoist controllers operating in this country, their inherent operating advantages can be noticed, and it is safe to predict that the future will see an increasing use of variable-voltage control on blast furnace skip hoists.

K. M. Raynor*: This data has been very instructive to me, as we have nothing in operation except D.C. skips, operated directly from our D.C. system. We have recently applied a system of automatic control for the operation of the bells. The bells are operated by the blast pressure, which includes nothing more or less than a few contactors and solenoids operated automatically to open and close the bells. This has eliminated three men at the furnace.

*Asst. Supt., Elec. Dept., Bethlehem Steel Co., Bethlehem, Pa.

C. P. Hamilton†: I also want to congratulate Mr. Anderson on his paper. I feel that it has given us a lot of valuable comparative data on the operation of skip hoists using Ward Leonard control and AC multi-speed motors.

The Ward Leonard system of control is certainly coming into its own on hoist applications during the past few years. The trend is very noticeable on passenger elevator installations as well as car dumpers, coal towers, ore bridges, and mine hoists. Its application to blast furnace skips is also being very carefully investigated by a number of steel mill engineers. This is shown by the fact that there are three in operation at the present time in the South in addition to this one now operating at Sparrows Point.

With the Kneeland top, such as at Sparrows Point, it is important that the bucket does not swing as it is seated. To eliminate bucket sway, the retardation from full speed to the landing speed must be smooth. A second important feature to be considered is to obtain a very slow speed from which to land the heavy bucket on the furnace top without shock to the structure. Also in picking up the loaded bucket from the tram car a slow speed is essential as otherwise the sway of the bucket will prevent the latch engaging the stem

†General Electric Company, Schenectady, N. Y.

properly. Thus, since a relatively high speed, 587 FPM on this hoist, is used, a broad spread in speeds is necessary for successful operation. The elimination of bucket sway and the broad speed range available are particular advantages of the Ward Leonard type of control. In addition to these two advantages, the Paper brought out the flexibility and lower power consumption as contrasted with the drive using a multi-speed AC motor. It is also interesting to note that the speed of the drive is about constant, both slow speed and full speed, regardless of the load. Furthermore, experience with Ward Leonard control over a number of years has indicated that maintenance expense in replacement of parts is practically negligible. The additional point may be mentioned of being able to use a high voltage A.C. motor to drive the M.G. set to obtain an economical power distribution system. So when all of these points are considered, along with the limited D.C. capacity available in many steel plants, Ward Leonard control is particularly well adapted to blast furnace skip hoists in general. And when it is remembered that a blast furnace represents a very heavy investment, and is dependent entirely on the skip hoist for its material, it would seem that this type of drive should be very carefully considered.

Fred O. Schnure*: I am very glad that Mr. Kennedy and Mr. Hamilton pointed out the fact that the Kneeland top is a very hard top to fill. We have to be very careful in accelerating and decelerating so as not to get the buckets swinging.

Back in about 1923 Mr. Cummins, of Duquesne and the late Mr. Leavitt published a paper in the Iron & Steel Engineer which compared the A.C. motor with two D.C. motors in series and also with a single motor skip. The data on the A.C. motor was from our plant. The data on the D.C. rheostatic motor was from his own plant. I do not know whether the figures he gave are calculated or actual, but the two motors in series parallel connection shows a little better efficiency than the Ward Leonard, 1.74 K.W. hours per ton on the A.C. skip, 1.55 the Ward Leonard, 2.16 on the single D.C. motor and 1.42 on the series parallel controlled motors. The Ward Leonard is really one of the most efficient of drives. One of the most pleasing features to us in this installation at Sparrows Point is the fact that the control is of such a simple nature. On the D.C. rheostatic drive, or the A.C. drive, the contactors are large and the maintenance is generally fairly heavy whereas on the Ward Leonard the control maintenance is practically nothing.

L. A. Umansky†: In the light of what we heard tonight it is interesting to compare the practice of electrification of Blast Furnace Skip Hoists here and abroad.

In Germany practically all skip hoists are Ward Leonard equipped. This is due to several reasons: In the first place, the German engineers fully realize the simplicity and flexibility of this type of control and its adaptation for automatic operation; secondly, the use of direct current, even for auxiliary drives and like, is considerably more limited on the continent than in U. S. A.; at the same time the development of magnetic control in Germany is some 10 years behind our own practice; thus with only a.c. power on hand the engineers naturally lean toward the Ward Leonard equipments with a rheostatic control of the generator field (as against automatic contactor field control as in the Sparrows Point skip hoist).

Contactor control devices have reached a somewhat higher stage of development in England and France than in Germany. D.c. is also more widely used around the plants. In some of the post-war French steel mills advantage is taken of this fact and skip hoists are equipped with d.c. motors, running from 250 volts d.c. supply and equipped with magnetic control. In other words, their practice is more or less similar to what has been considered standard with our plants until very late. It must be remembered, however, that the French and British blast furnaces are much smaller in capacity than ours (seldom more than 300 tons) and that, therefore, the skip hoist speed is much lower than is needed for our new blast furnaces.

As the skip speed is increasing and as the frequency of trips goes up to keep pace with the increase of tonnage, the rheostatic losses acquire more and more importance, and the control requirements as to accurate speed control throughout the travel, independent of load, become ever more exacting. Here is where the Ward Leonard control comes fully into its own. There is nothing more flexible and more adopted for changes from time to time as conditions vary. When we realize that the efficiency of these Ward Leonard drives is also superior, then it looks fairly certain that all new blast furnaces will be similarly equipped.

This is the principal reason why, I believe, we should be particularly indebted to Mr. Anderson for his interesting and valuable paper, with such wealth of material and operating data.

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†Industrial Engr. Dept., General Electric Company, Schenectady, N. Y.

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Employees Training For Combustion Work †

By W. P. E. AINSWORTH*

The training of men for the operation of complex and involved machinery has been an important problem in American Industry. Much time and energy has been devoted by engineers in determining how we can best prepare our employees to assume those responsibilities that modern production practices involve.

In general, the development of mechanical equipment progresses only so fast as the ability of the operator to handle it efficiently. The controlling factor is the human being not the machine. If we examine the machine shop we find that standardization of production processes and the development of specialists in limited vocational fields has permitted a substantial increasing of the efficiency of the shop organization as a whole.

We have not brought down our production costs or placed ourselves in a favorable competitive position in world markets until we have achieved the creation of the expert in restricted fields rather than the all around mechanic in a diversified employment. This general principle is applicable to a majority of our production processes but is not strictly applicable to the matter of training men for combustion work.

In combustion we deal with a number of variable factors. Coal, our most common fuel, is perhaps the most complex and varying substance in nature. The science of combining fuel with air in the proper proportions and quantities to produce certain results is a science in itself. Not very many years ago the problem was relatively unimportant but increasing fuel costs and the demands of our modern industrial life have materially altered the situation. During the last decade we have seen some rapid strides in the design of boiler room equipment. Boilers have increased in size from several hundred horse-power to several thousand; furnace designs have been revolutionized to accommodate higher combustion rates and new methods of burning coal; pressures have increased until 1,800 lbs. or higher is considered commercially practical. This progress has not been confined to the central stations. Industrial plants, also, have shared in it and as a matter of fact are doing considerable pioneering, especially in the field of firing combinations of various fuels such as pulverized coal, blast furnace gas, tar and other substances.

Volumes have been written on these subjects and the best technical talent has been devoted to the study of new designs to effect economy and efficiency in heat liberation and absorption. But while these changes have taken place and while we have refined the machinery of the boiler room just what have we done to insure the ability of the men in the boiler room to meet the demands that are being placed upon them?

How have we met the problem of insuring the return to us of the economies inherent in the apparatus existing in our industrial boiler plants? Whether the plant consists of a few hundred boiler horsepower hand fired or a modern pulverized fuel installation it has a certain obtainable efficiency. We can draw a curve plotting efficiencies against capacities obtainable under the best operating conditions. It may represent what we can expect if that plant is operated under test conditions by engineers highly skilled in their work.

Somewhere under this curve and maintaining the same general contour of the test curve we can draw another that will represent the efficiencies being secured under normal operation by the plant organization. The area between these two curves represent the avoidable loss in fuel. It also represents the opportunities existing in that plant for the application of combustion training. The object of this training is to make the curve of actual results approach as near as possible, or coincide with the curve of maximum obtainable results.

The training of a boiler plant organization depends in general upon three factors:

First: The type of apparatus in use.

Second: The grade of talent available for operators.

Third: The size of the boiler room organization.

In the case of the first factor; namely, the type of apparatus, the influence is obvious. In the small hand fired plant instruction is more elementary. In the highly developed modern plant the amount of expensive machinery and the quantity of fuel intrusted to the individual operator warrants the selecting of a high type of man. In the case of the modern plant it must be realized that while the possibilities of fuel economy are great, it is also a fact that the ignorant and careless operator can be a vastly greater financial hazard than he would be on the more simple and less refined types of equipment. Present day designs have made available the greatest flexibility in operation with the least work on the part of the men in charge. It is foolish to spend the money and pay the premium for these various refinements unless we make sure the brains are up to the standards of the equipment.

The second factor, or the grade of available talent, refers to more of a geographical condition. Many plants find it to their advantage to locate near the source of their raw material. It may be a location in an agricultural region or in timber country. In such sections men with combustion experience may be scarce or non-existent. Under such conditions a basic organization can be imported but to a large extent such plants must depend upon the available labor to round out and complete their personnel requirements. Talent of this sort naturally requires a more complete and fundamental basic training.

The third factor is the size of the organization. This will influence our judgment more as concerns methods than the scope and extent of training. In the small plant there is a chance of individual instruction. The combustion engineer can spend considerable time with each operator and the chief engineer can check, advise, and which each man continuously. In the large organization individual in-

†Presented before Combustion Engineering Division of the A. I. & S. E. E., January 23rd, 1929, at Pittsburgh, Pa.

*Combustion Engineering Corporation, New York, N. Y.

struction is important but it must be supplemented systematically with written instructions and routine training.

Before beginning the training of an organization the first thing to do is to analyze it. In general there are two types of men. Those who have the ability and willingness to learn and those who lack either the ability or willingness. The second class should be eliminated from any consideration and relegated to jobs best fitted for their mentality. The first class are those who are going to give a return for an effort. Sometimes we are inclined to believe that this class is regrettably small. If men of the proper type are not available in sufficient numbers the thing to do is to go outside and get them rather than try to do the impossible.

While on the subject of selecting an organization it might be in order to inject a thought with regard to the employment of men as boiler and furnace operators. When employing a man for the operation of a certain type of equipment, pay particular attention to his personality and discount any previous experience he may have had on similar equipment elsewhere until you can verify his record.

Long years of association with a particular machine such as a certain type of stoker is frequently more of a liability than an asset. This problem is most apparent to the manufacturer. In scores of instances service engineers report to place new plants in operation and find that customers have gone out of their way to employ men who have operated similar equipment elsewhere. In a large percentage of such cases it takes longer to knock incorrect notions out of the heads of such men than it does to teach a perfectly willing but green crew how to operate the equipment.

The training of employees in combustion logically starts with instilling in them as comprehensive a knowledge as possible of the fundamentals of the principles of combustion.

What is CO_2?

Of what does coal consist?

What is the significance and the cause of the reactions we observe in the furnace?

This teaching of fundamentals is the most difficult phase of the training and the selection of our course of action must be controlled by the mental development of the individuals concerned.

Perhaps the most common and one of the most satisfactory ways of accomplishing basic instruction is by means of the recognized and sound correspondence course. Many companies recognizing its advantages pay for such instruction. If such courses are free of cost to employees, however, there will be a certain amount of dead wood in the form of men who are anxious to appear ambitious but reluctant to study. One way to deal with this situation is for the company to urge selected employees to subscribe to a certain recommended course with the understanding that if the employee passes with creditable marks the company will reimburse him for the cost. Money spent in this way is soundly invested. Courses are available which are sufficiently technical to accomplish this purpose and at the same time adequately clear in language to avoid confusion in the mind of the man who has not had many educational advantages.

A second type of instruction is that given the operators by the company's combustion engineer, if the company has one, by a representative of a competent consulting engineer, or by an engineer obtained from the manufacturer of the equipment. Practically every representative manufacturer of combustion equipment maintains a corps of men trained in the operation of their products as well as in the general methods of power plant operation. These men are usually delegated by the manufacturer to issue the preliminary operating instructions when the apparatus is first placed in service.

The combustion engineer can tell the operators how to handle their work and show them how to perform their duties, but regardless of how well he does his job there must be frequent and periodic checking by the engineer in responsible charge of the plant to see the instructions are being carried out and to note and act on any apparent reluctance on the part of operators to follow these instructions. The chief engineer is responsible for operating results and not only must he keep his subordinates on their toes but he must know the equipment as well as his subordinates if he is to expect to command their respect. Many a plant has been cleared of operating troubles by teaching the chief engineer how to operate a stoker.

It is regrettable that many plant engineers resent the suggestion that an outsider can be of any service to them in instructing their force and reviewing their operating records. This attitude is costing industrial plants hundreds of thousands of dollars annually in absolutely avoidable losses. There are many examples of what an expert called from the outside can accomplish. To cite an example. About two years ago the mechanical engineer of a prominent eastern industrial plant called for a service man to review his operation. There were only three boilers in the plant and they were of a well-known standard make, fired in a very orthodox manner by stokers. The plant had been started in operation by a very competent engineer about five years previously. During that period there had been a certain turn over of the operating force, including the chief engineers, and a gradual slipping in the methods used in the handling of the stokers.

A service engineer was sent by the manufacturer and about ten days' time was spent restoring draft gauges to an operative condition, adjusting the stokers, and teaching the plant engineers and firemen how to run their equipment.

The cost of the service engineer's time was about $200.00. The plant management estimated their savings in coal the following year to exceed $20,000.00. Just how much money had been wasted during the previous years is problematic but it would have gone a long way in building a duplicate plant.

The trouble in this one of many cases did not lie with the operators. It rested squarely on the shoulders of the plant management because of their indifference to, or ignorance of, the necessity of arranging an intelligent periodic check of their organization and its methods of operation. They would not think of going a year without having their treasurer's books audited, but they turned over $75,000.00 in fuel to a group of unskilled men to spend without the semblance of a check.

The third method in training employees or boiler room operators might be called demonstration. It is showing the men the correct way of handling their equipment by means of visits to other plants. As a

rule this is a practical method only in industrial districts where it can be done without the expense and time incident to travelling a long distance. There is one important point to keep in mind and that is of course that the plant visited must be worthy as an example. This should be carefully determined.

Manufacturers have found such visiting a very effective way to demonstrate the operation of the apparatus and to give the operators a comprehensive idea of what the proper kind of a fire looks like and how it is controlled.

A well-known psychologist has said that the average human being preferred staying in a rut to the effort of getting out. In many plants we find men operating incorrectly in spite of advice of service engineers, and actual demonstrations on their units of correct methods. An appeal to their pride by showing them what other operators accomplish has solved this trouble in many boiler rooms.

Some employees have the preconceived notion that the best way is the hardest. No attitude is more false than that. In the operation of combustion equipment the best way is in the long run the easiest, and if we make an appeal along these lines more will be accomplished than in attempting other methods of obtaining results. Among such other methods we have the bonus system through which we reward certain shifts or individuals for maintaining the best CO_2 or the best evaporation. The bonus system is all right if it can be equally enforced but the weak points are many. Different ratings prevail on different shifts and variations in rating result in variations in obtainable efficiencies and evaporations. In extreme cases we find falsification of records an unscrupulous attempts to obtain the credit which carries with the extra bonus money. If the bonus system is contemplated it behooves us to consider carefully before making a decision.

I would like to say a word about automatic regulation of boilers. Automatic regulators are designed with the object of doing mechanically with greater precision and accuracy that which has been the function of the operator. In properly burning such a complex substance as coal, no matter how accurately a regulator is designed, or how elaborate the system, until such time as it is endowed with brains some one must oversee its operation and determine that it is performing when and how it should. No operator can be expected to make an intelligent check of the performance of an automatically regulated boiler unless he has a thorough and complete knowledge of just what is supposed to take place in the boiler and furnace. He can know this only by first doing the work himself.

The suggestion is earnestly offered that in all cases where fuel burning equipment is first placed in service that the operation be conducted without any automatic regulator for a sufficient period of time to permit the men who are going to be responsible to know from personal experience how the stoker, or the pulverized fuel equipment, or the oil burners, or gas burners are supposed to work to deliver results. You can then hook up your regulator with the knowledge that the conditions it maintains are being checked by individuals who know just what is to be expected of the equipment.

In conclusion may I say that the question of training is one that concerns itself not with changes of apparatus or the building of new plants but with the question of getting everything obtainable from the equipment at hand. No hard and fast rules can be established. Conditions in the plant influences our course of action. We are dealing, not with certain known forces and reactions. We are dealing with the most involved and mysterious problem of all engineering—the human equation. Our job is to bring the human machine progressively to higher intellectual standards so that we may anticipate the constant development of our industrial machinery.

In closing I wish to quote from an interview with Mr. Edison, which was published early this month. Mr. Edison stated "A machine age cannot be a stupid age. It has to be a highly intelligent age." A workman who is only a human machine without intelligence cannot operate or supervise a highly developed piece of machinery. We already have some machines which would considerably decrease the costs of production if only we could get men of high enough intelligence to operate them. A machine age demands a high level of human intelligence."

The Recognition of the Engineer As An Executive

(Continued from page four)

unfavorable to engineers as a body, it seems very probable that some of the white light of publicity which shines on the occupant of the White House may be reflected in some degree on them. Based on their established record of accomplishments in the past, they may be expected to withstand public scrutiny with credit to themselves and their profession.

It will be an indifferent engineer indeed who does not scan the news from Washington with added interest after Mr. Hoover's inauguration. Observing the actions of an illustrious member of his own profession as he directs the affairs of the richest and most powerful nation on the globe should excite his keenest interest. No engineer of modern times has ever had such power bestowed on him before. How will he discharge his obligations, what will be his methods, what will be the factors of strength and weakness disclosed in the public actions of this man, to what extent will the methods of an engineer fit into the needs of government, how may similar methods be applied in other affairs of human kind; will they provide a new means of handling the political questions which beset our country from all sides; will they lighten the burdens of the masses and help banish poverty from our land as Mr. Hoover desires. Time and trial alone will answer these and a myriad of other questions. Let the steel mill engineer watch the progress of events as they parade across the public view and each one apply to his own affairs the lessons gained therefrom. Above all, let each one in his small way lend support and encouragement in this experiment in popular government which bears a full measure of promise for our country's welfare.

Selection of Electrical Equipment for Arc Furnaces Used in the Melting and Refining of Ferrous Metals

By SAMUEL ARNOLD 3rd*

The arc furnace for use in the melting and refining of ferrous metals was introduced in Europe, and although it has made considerable progress there, its greatest development has been in the United States. The Heroult Furnace was the first successful type of unit utilized in the United States, and directly preceding and during the World War a great number of these furnaces were put into commercial use. About this time there were numerous other designs of furnaces which came into the market. It might be said that none of these freak type furnaces have been successful and that practically all commercial furnaces in use today are of the Heroult type.

There is of course, some difference of design in the various makes of successful Heroult type units, but the essential element of utilizing three electrodes spaced at 120 degrees and suspended vertically through the top of the furnace is characteristic of all successful furnaces today. Different methods are used for tilting and different arrangements are made in regard to the operation of the electrode arms, but this one essential characteristic remains. During the war also, numerous designs of furnaces were equipped with single phase, two phase and mongrel three phase connections and some furnaces had bottom electrodes. Even today, there is one successful make of furnace on which a bottom grid is usually placed, the furnace shell being connected to the neutral of a Y connected transformer through a knife switch; however, this connection is not often utilized as the switch is usually left open.

In the selection of proper electrical equipment for arc furnaces of the Heroult type, items of design are sometimes included which, although accomplishing what is immediately desired, materially effect the average operation, and for this reason, conditions are obtained which do not give the best average operating results. In many cases to accomplish a single object, certain sacrifices are made in the design of parts and the application of power that cannot be compensated by the single result obtained. It is therefore, essential that the electrical equipment on efficient arc furnaces must be so designed, that the furnaces are well balanced to give the best over-all conditions.

As electric power is expensive, it is of course, always desirable to obtain the greatest efficiency. If it were possible to insulate arc furnaces, much higher efficiencies could be obtained, but due to the temperature range and the inability of present day refractories to withstand the high temperatures necessary, efficiency obtained by insulation must be sacrificed on account of refractories. Careful design of electrical equipment, bus and cable structure, and especially the conductors carrying the current over the furnace will aid in increasing the efficiency; and inasmuch as radiation plays the most important part in obtaining furnace efficiency, it follows that the one logical opportunity to decrease radiation is in cutting down the time of radiation. As the time factor during the refining period is changed only by metallurgical practice, and as it is dependent on the grade of material to be produced, the best opportunity for decreasing the radiating period is in the melting down operation, and for this reason a high melting rate is important. Unfortunately however, other factors are introduced in securing high melting rates, and it follows that quick melt should not be considered above all else. If power is forced into the furnace at such a rate as to build up a high temperature gradient, increased refractory losses will result and the saving in power will not be compensated by the increased refractory cost. There is also, another item to be considered, that of demand charge. Often the increased power cost on account of high demand, is considerably in excess of the energy saved. Frequently high production is the only thought, but in the last analysis, over-all cost with consideration of the product produced is the real basis for calculating results. The proper economic power input for a certain charge is still more or less of an open question, but keeping the furnace under an established full load condition during the melt is unquestionably a step in the right direction, and the choice of the proper voltages together with the correct amount of reactance is highly important in obtaining full load during the melt with consideration given to the proper length of arc in order to minimize refractory losses and excessive radiation.

In the selection of proper electrical equipment, attention should be given to the following:

1st. Correct transformer capacity for the size of furnace used and for the work it handles.

2nd. Proper voltage range and control, together with the correct amount of reactance for each voltage applied, all of which are direct factors of the size of furnace, transformer capacity, method of operation and material to be produced.

3rd. Proper design of bus and cable structure.

4th. Proper application of regulating and metering equipment.

5th. Proper switching equipment.

In choosing the correct transformer capacity it must be remembered that practically all power schedules exact demand charges, and although it

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Presented before Electric Heating Conference, State College, Pa.

would be ideal to force power into the furnace to the limit of the refractories, the efficiency gained is often offset by the increased demand charge. Again some furnace operators claim that the high temperature and high voltage used in gaining very rapid melt is detrimental to high grades of steel, this due to oxidation and dissociation. Although the point is yet an open question, it should be given consideration where high quality is paramount. In general, transformer capacities should be ample and the trend is towards higher capacities. It is always safe to have the transformer of large size as melting conditions and the type of material produced vary, and the refractories are constantly being improved. Another item in the selection of the transformer that is not often given consideration is that taps should be arranged so that with series parallel and Y connections on the secondary, standard power voltages could be obtained, and thus, in case it is desired at some later date to use the transformer for other than furnace work, it can be employed on standard power circuits.

In almost every case where a pure water supply is available three phase water cooled transformers can be utilized, and they have the advantage of occupying less space and being somewhat cheaper in cost. The water necessary for furnace use is very little more with water-cooled transformers than with self cooled units, as the transformer cooling coils can generally be placed in series with the furnace supply. It is generally conceded that transformers are best connected delta delta, Y delta or delta Y delta, and as the primary is the ideal side of the transformer to be utilized for switching, furnace transformers are more frequently connected in permanent delta on the secondary, although Y connected secondaries are also used. With the secondary of the power transformer connected delta, both ends of each phase of the primary winding can be brought out with as many taps as desired and this offers a very flexible arrangement for obtaining furnace voltages by means of several delta or Y arrangements.

It was originally customary in the operation of electric furnaces to provide a single voltage for both the melting and refining operations. Such a voltage was not satisfactory for either of these conditions, as it was necessary to effect a compromise and utilize a voltage which was entirely too low for proper melting, and at the same time too high for proper refining. In order to overcome objections such as existed with the single voltage system, dual voltage control was provided, by means, either of taps on the transformer or by Delta Y connections. Such a system was inherently better in that it provided one voltage which could be high enough for effective melting and another low enough for refining. This scheme also had definite disadvantages in that the high voltage at the beginning of the melt caused considerable surging until the electrodes were buried in the scrap and a pool of molten metal was formed, and if a low voltage were used in the beginning of the melt, difficulty would be encountered in obtaining the proper contact between the electrodes and the charge, and much time would be lost in burying the electrodes in the scrap and forming a pool of fused metal. Again, very near the completion of the melt the long arc playing above the nearly molten bath radiated heat and caused reduced refractory life, and if the refining voltages were used at this time it would lengthen the final melting period because sufficient power would not be available. The use of the long arc at the end of the refining period, particularly on basic furnaces in making the second slag, also tended to produce undue heating of the steel directly under the electrodes, and if the power input were reduced with the same high voltage, the arc would be elongated excessively with increased refractory troubles. For these reasons, a refining voltage higher than that most desirable, was chosen with necessarily poor results when again used during the main portion of the refining period.

To overcome these many difficulties in the operation of arc melting furnaces, practically all modern installations are made with some sort of multiple voltage control. The ideal way to obtain multiple voltage control would be with an inductor regulator, or by means of a multiplicity of taps on the primary side of the power transformer. But as this is prohibitive from a cost standpoint as well as from a standpoint of complications to the sub-station equipment, most of the installations have been made with a choice of three or four voltages at the will of the operator. These voltages are secured by multiple delta and Y connections on the primary side of the power transformer, utilizing electrically operated oil circuit breakers for switching. On the installations as already made the transformers have been provided with 9, 12 or 15 loads brought out of the transformer case to permit the delta and Y connections. It is not always necessary to bring extra loads out of the transformer case, but it is desirable as it permits forming delta or Y connections on any tap. In other words with the correct number of leads brought out it is not necessary to form the Y voltage corresponding to a certain set delta voltage. External reactors are necessary and desirable on the smaller furnaces, but their use depends entirely upon the reactance of the furnace itself. In general, with transformer capacities up to and including 2500 KVA, external reactors are used on the high or delta voltages. The reactors are provided with taps so that a choice of the proper reactance may be made for each different furnace voltage. Usually no external reactance is connected in the Y circuits which give the lower voltages. This proper proportioning of external reactance for the voltages selected, in connection with the combined transformer and furnace reactance at the various power inputs utilized, gives the proper total reactance for most efficient power factor commensurate with best regulation.

There has been much discussion as to the overheating of the molten bath and its detrimental effect on the material produced; unquestionably there is some effect of this kind, but just how much, is not definitely known. With the proper length of arc for meeting the conditions in the furnace especially after the charge is approximately melted and for breaking up slags and furnishing losses during the refining period, an almost ideal condition is realized for metallurgical purposes and for reducing as far as possible refractory losses. Although with a choice of three or four voltages this ideal condition is not always obtained, it closely approximates the most

desirable and is unquestionably practical as evidenced by furnaces now in operation.

In connection with the uses of reactance, there are in general two types of reactors utilized: air core and iron core units. Both have their relative advantages and disadvantages. Air core reactors have ideal characteristics for furnace work but have the disadvantage of occupying more space and introducing hazards when considered from a safety standpoint. Iron core reactors, designed with ample capacity so that the working range is well below the saturation point, have characteristics which are very similar to air core reactors, and occupy less space, but as a rule they are more expensive. In some cases reactors are built into the transformer tank. This arrangement is considerably cheaper than utilizing external units, but it has the disadvantage of being less flexible. In case high transient voltages occur, due to lightning or other causes, the reactor is generally the first part to fail. With external reactors the furnace can be put into operation with the reactors cut out until they are repaired, but with reactors built into the transformer tank, the transformer must necessarily be disconnected until the reactors are again put into service. Another disadvantage of the reactors built into the transformer tank is the fact that the transformer unit is necessarily large, and the handling of this large unit is objectionable.

In the design of bus and cable structure it is important to gain effectiveness from the copper utilized, and particularly on the larger furnaces, to eliminate as much reactance as possible in the transformer connections, cable structure and bus structure over the furnace. The analysis of the methods to be used to get sufficient current carrying capacity and at the same time obtain a good power factor is a problem in itself. Bus structures are usually of two types; rolled copper bars or copper tubing. Rolled copper bars are frequently used in forming the transformer delta connections and the bus structure from the transformer to the flexible cables. In the design of bus structure with copper bars, attention must be paid to proper ventilation, proper contact area and above all proper arrangement to minimize skin effect and reactance. Copper tubing offers the best method of carrying the current over the furnace, as it is the ideal conductor to reduce skin effect, and also because it lends itself to water cooling, which is of great advantage where bolted connections must be made to facilitate the removal of parts such as electrode holders.

There are two types of regulating equipment in use in the United States which may be termed, contact making ammeter control and contact making wattmeter control. Both are good. Both give excellent regulation and both have their relative advantages and disadvantages. In general it might be said that the contact making wattmeter control gives somewhat better regulation but is more delicate of adjustment. In the use of a contact making wattmeter type of regulator, constant speed electrode motors should be furnished. These motors should be equipped with ball or roller bearings and geared to give an electrode speed of approximately 3 ft. per minute, which speed is obtained on operating the hand control, the regulator cutting down the speed when the furnace is operating automatically. The contact making ammeter type of control is best utilized with variable speed motors, the high speed for use on the hand control and the low speed for use when the furnace is working automatically. Different types of furnaces have different arrangements of electrode winch mechanism. Some use a direct pull on the electrode arms with the winches fastened to the furnace shell. On other units the winches are placed in the transformer vault and the electrode arms counterweighted. This last method permits the use of smaller electrode motors and winches. The proper metering equipment is essential so that the furnace operator knows what is going on in the furnace and so that the plant engineer may be able to check up proper operation and make necessary adjustments. In general, three ammeters are had for showing the furnace load, and a watthour meter to record the amount of power utilized per heat. In addition to these absolutely necessary instruments, it is good practice to furnish a volt meter connected on the secondary side to show the voltage in use; a polyphase indicating wattmeter to give a total reading of the power used, and a curve drawing wattmeter to keep a record of each heat. This curve drawing wattmeter is particularly advantageous where an accurate record of each heat is wanted and it very definitely shows the cycle of operation, length of time required to charge, time lost for one reason or another, and is indeed an excellent check on furnace operation. Frequently power factor meters are included and in nearly every case ground detector lamps are furnished and connected between each phase and the neutral. These lamps by their relative brilliancy often aid the operator in maintaining proper furnace conditions. On the switchboard are also mounted the necessary overload protective relays which unquestionably should be of the induction type as the old bellows or plunger type often become inoperative on account of the accumulation of dirt and dust.

In the selection of proper switching equipment, care must be taken to consider the capacity of the incoming line and the amount of energy that may be piled up in case of a shortage. Here again the local conditions influence the design and arrangement and if the customer has a substation equipped with circuit breakers of sufficient capacity, smaller breakers may be utilized at the furnace. Where conditions such as this are found, it is desirable to use the current transformers on the secondary side of the power transformer for tripping the main breaker. Due to the reactance of the furnace circuit it will be impossible to get over-loads in excess of the breaker capacity and in case of transformer failure or a failure in the primary circuit, the main furnace breaker would not function, and as a result the sub-station breaker, which is of larger capacity would open the circuit. In case the power company had a sub-station located near the customer, this same arrangement could be made and the power company's sub-station breaker would take care of these extreme conditions. Where no external substation protection, either on the part of the company operating the furnace or on the part of the power company is available, it is always good practice to trip the furnace breaker from the current transformers on the primary side of the power trans-

former, and use a line breaker of a rupturing capacity, required by the feeder circuit.

In obtaining the various secondary voltages, use can be made of delta, Y and series parallel connections on the secondaries of the power transformers, but due to the fact that heavy currents are handled it is generally conceded that the best method of switching is on the primary side of the power transformer. Oil circuit breakers are usually chosen for this primary switching to form the various delta and Y arrangements. Electrically operated and electrically interlocked air break switches have been proposed, and, in some cases utilized for this work. In general there is no saving in cost of equipment by this method of switching, on power lines under 15 K.V., but there is some saving in cost of equipment at the higher voltages. On the other hand there are objections to air break switches from a standpoint of safety and at the present time the additional cost of oil circuit breakers seems to be warranted. In all cases where air break switches or oil circuit breakers are employed, the switches should have a sufficient voltage rating to take care of any over voltages produced in the end windings of the transformer when the lower taps are in service. It is also essential to interlock the tap changing breakers both with themselves and with the main breaker, and as mechanical interlocking is cumbersome and usually difficult from a practical standpoint, electrical interlocking is the method generally used. This by proper application can be accomplished with safety and freedom from trouble.

It is never desirable to operate the tap changing breakers with the main breaker in, and the transformer alive, for in opening the delta or Y primary circuit, conditions may be had where all three poles do not operate simultaneously and there is a possibility of high transient voltages being set up. As an example on a furnace transformer fed from a 22 K.V. circuit, transient voltages were observed in excess of 70 K.V. when the delta was opened. In general, it may be said that the choice of proper switching equipment for electric furnaces is an engineering problem to be worked out for each particular case, and full knowledge should be had of all local conditions of power supply before the proper switching equipment should be specified.

Careful attention should also be paid to metering transformers. It is always desirable to operate the wattmeters from the primary side of the power transformer as these meters will include the transformer losses and give a true value of the amount of power necessary for operating the furnace. While this is in general, the practice among most of the furnace builders, there have been some installations made where the wattmeter supply is obtained from the secondary side of the power transformer. As a majority of the power companies have their circuits insulated greatly in excess of the normal voltage rating of their lines, it is desirable to furnish instrument transformers that are connected on the primary, with sufficient voltage rating to take care of any surges and unusual conditions. If the instrument transformers are not built with sufficient insulation they become the weakest part of the line and on unusual conditions fail with resultant furnace shut down.

From the standpoint of safety, freedom from trouble and good operating conditions, special attention should be given to the layout of apparatus and the general primary scheme. The transformer vault of an electric furnace is a sub-station and should be constructed as such. It has been said that a job on which care has been taken to make a good appearance, is usually a good job, and slipshod and careless wiring or placing of high tension equipment should never be tolerated.

The selection of electrical equipment of arc furnaces has in the last few years been given much more attention than formerly and each particular installation is usually a problem in itself. It is almost impossible to standardize on electrical equipment as the art is rapidly changing, new ideas are being brought out from time to time and the near future will, no doubt, show still further advancement.

Application of the Automatic Substation to Steel Mill Service

By A. P. DING*

THE growth of the steel mill industry from infancy to its present-day status occurred within a span of less than fifty years. As in all other processes intimately connected with science and engineering, new developments are matters of almost everyday occurrence. In the early days with hand-operated equipment alone available, the steel manufacturing process was necessarily slow and laborious. The demand for increased production, superior quality and wider variety of forms; the change in labor conditions, especially that resulting from the advent of the 8-hour day; the pressure of keen competition necessitating a reduction in operating expense; and the realization of the advantages of electrical equipment in the mill, finally led to the installation of the first electric drive in 1905.

Like other ventures into new and untried fields, one of the greatest difficulties encountered was that of proving the efficacy of the innovation. The experience of the pioneers quickly demonstrated its possibilities, and rapid strides were made in the in-

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creased use of electricity in the production of steel. Hundreds of millions of dollars have been spent by the big steel companies in plant improvement within the last few years and the trend of the industry is distinctly toward electrification.

The automatic substation finds its chief application to steel mill work in supplying power for mill auxiliaries, such as, cranes and ladles for mill motors of smaller capacity, and for direct connection to the d-c. network.

ADVANTAGES

Some of the outstanding advantages to be derived from automatic installation are: Reliability of operation, speed in rendering additional power available for load, continuity of service, and economy in operation from the consideration of labor cost, power loss, and copper requirements.

By a system of interlocking which prevents the operation of any step in the sequence, without the proper functioning of each and every previous step, false operation is avoided. Where proper and intelligent maintenance is provided, the equipment functions with such amazing precision and reliability that it has removed the last doubt in this direction.

Many occasions arise when an additional source of power is required on the shortest notice. In this case, high speed in starting a machine and connecting it to the load is an extreme necessity, and automatic equipment answers this requirement admirably since the time required for this operation is much less than that necessary with a manual equipment.

Because of the enormous loss that is liable to arise from a single failure, the demand for continuity of service must be met regardless of bad bus voltage or overloaded equipment. The short-circuit selective feeder developed for this application is unusual in its ability to differentiate between short circuit and legitimate overload. The power is not disconnected on overload, but only on short circuits. After once opening, the feeder will stay open as long as the fault remains, but it recloses immediately when the fault has cleared. These features of supplying power regardless of the size of the load, tripping on short-circuits only, and reclosing without delay upon removal of the short-circuit contribute in no small measure to the continuity of service.

OPERATION

Both full-automatic and semi-automatic controls are used. With a full-automatic scheme of control, the station is started when there is a demand for power as made evident by some electrical condition, such as low bus voltage. Shutdown is also accomplished through the agency of some electrical condition, such as underload on a machine for a certain period. This scheme of control is applied when a material saving can be effected by shutting down under light loads, and when it is undesirable to have an attendant start and stop the station.

With the semi-automatic scheme of control, the station is started by the manual operation of some device, such as a push button, and the operation from this point on is entirely automatic. Shutdown is accomplished in a similar manner. Advantage is also taken of remote control. By this means, the starting impulse may be initiated by a push button, control switch, or other similar devices located at a distance; for instance, at the power house, or a manually operated substation.

The operation of both types of equipment after receipt of the starting impulse may be exactly alike. In the following, the operation of a semi-automatic motor-generator set with reactance starting is described. The main steps in the operation are not different from those in the operation of a manual set. The motor is started by connecting through reactors to the a-c. supply, the reactors short-circuited when the machine comes up to speed, the machine voltage balanced against bus voltage and the d-c. breaker closed, followed by the closing of the feeder breakers, the same as in a manual set. The starting procedure is practically the same when auto transformers are used.

In both types of equipment, the starting and stopping of the station is dependent on a master relay. When this relay is energized, the entire train of operation in the sequence is initiated and when once it is de-energized, all of the relays, contactors and breakers are caused to drop out and the unit is shut down.

STARTING

The operation of the starting element (such as a push button) energizes the master relay. This, in turn, causes the closing of an oil circuit breaker to connect the motor to the a-c. power through reactors, and then the motor is started under reduced voltage.

A motor field contactor is provided which is hinged at the middle and which has an upper and a lower coil. During the starting period, the synchronous motor field circuit is short circuited through the discharge resistance by means of the lower contact, and series coil of the above mentioned contactor. While the unit is building up in speed, an a-c. current is induced in the motor field and circulates through this circuit.

The upper coil of the contactor is tied across the exciter voltage and the potential impressed across the relay is increased as the exciter voltage builds up, but the action of the lower coil cannot be overcome as long as there is alternating current induced in the motor field, or, in other words, as long as the machine has not attained synchronous speed. When the unit has reached approximately synchronous speed, the current in the lower a-c. coil of the field contactor disappears and the action of the upper coil causes the motor field to be disconnected from the discharge circuit and connected to the exciter leads.

The exciter voltage is checked next, and if its value is satisfactory another oil circuit breaker is closed to short circuit the reactors, thus applying full voltage to the motor.

CONNECTION TO D-C. BUS

The next piece of apparatus to come into operation is the three-element d-c. regulator. The first of the three-elements is called the voltage balancing element. This element has two coils connected across the machine and bus voltages much in the same manner as a differential d-c. voltmeter. Dependent upon whether the generator voltage is below or above bus voltage, one of two sets of contacts is closed to operate the generator motor field rheostat to raise or lower the generator voltage.

When the generator voltage is equal or slightly above the bus voltage and remains so for a short time as an indication of a stabilized condition, the generator breaker is closed and the machine connected to the bus.

VOLTAGE REGULATION

When the main d-c. breaker is closed, the voltage balancing element of the regulator is disconnected and the two other elements—the voltage regulating element and the current limiting element are brought into play. The voltage regulating element regulates for constant voltage on the bus. In order to provide for parallel operation of several units, it is necessary to give the machine voltage a slight droop so that as the load on the unit increases, its voltage will drop, thus shifting some of the load to the other machines on the bus. This feature is secured through the current compensation by a second winding which is connected across the commutating field of the generator. The amount of droop becomes a function of the load since the current flowing through the compensating coil of the element is dependent upon the voltage drop in the commutating field, which, in turn, is directly dependent upon the load which the generator is delivering.

LOAD LIMITING

The third element of the regulator, called the current limiting element, is connected across the commutating field of the generator and operates to keep the machine within a certain load limit. Since motor-generator sets for steel mill service are usually built with overload ratings of 150 per cent for two hours, advantage is taken of this rating by calibrating the main coil of the current limiting element to regulate for 150 per cent load on the generator. A thermal relay connected across the commutating field is calibrated with characteristics similar to the heating of the generator windings. When the generator has been carrying 150 per cent load for approximately two hours, the thermal relay closes a contact which completes the circuit to an auxiliary winding on the regulator element. This second winding re-calibrates the element and limits the generator to full load. The generator will now be kept within full load limit until the machine windings have cooled sufficiently, at which point the thermal relay will re-open its contacts to restore the element and the generator to the original condition.

The voltage regulating element and the current limiting element both function by operation on the generator motor field rheostat. In order to raise the generator voltage, it is necessary that neither the regulated load nor the regulated voltage is exceeded, but the generator voltage may be lowered at any time by either element, or in other words. either element takes control depending upon whether the load or the voltage is excessive.

SHORT-CIRCUIT SELECTIVE RE-CLOSING FEEDER

Short-circuit selective re-closing feeders are usually supplied for steel mill application. Due to the nature of the steel mill load, the power must not be disconnected on account of overloads, but on short circuits, only. An impulse coil, which is a current transformer with a gap in its core to prevent saturation, is inserted in the lead of the feeder. In case of an overload, the increase in current is not rapid enough to induce sufficient current in the impulse coil to cause operation of the equipment. But in case of a short-circuit, the rapidly increasing current induces a momentary current in the impulse coil. This momentary current is used to operate a relay which, in turn, trips out the feeder breaker, thus disconnecting the power supply.

As soon as the breaker is tripped, the d-c. reclosing relay measures the load resistance. As long as the value of this resistance indicates that short-circuit conditions exist, the feeder breaker will remain open, but as soon as the load resistance rises to such a value that the breaker may be safely reclosed, the circuit is re-established.

STOPPING

When the stopping device is operated, the master relay is de-energized. This relay cause the d-c. breaker to open to disconnect the generator. After this has been accomplished, the a-c. breakers are tripped, the exciter field disconnected, and the motor field short-circuited through the discharge resistance. All of the remaining relays and contactors are de-energized so that the equipment resumes its original shutdown position.

MULTIPLE UNIT SUBSTATION

In case of several sets within a station, the lead-off set is started up in the usual manner. The starting up of the succeeding unit may be initiated either by the operation of a push button or by overload upon the preceding unit or units for a certain period. The shutting down of the unit may be accomplished by the operation of the "stop" push button or by underload on all the units for a period, the machine sequence being in the reverse order.

PROTECTION

Since the substation is left unattended after being started, protection must be provided against all contingencies. Protective features provided are as follows:

A-c. single or reverse phase.
A-c. low voltage.
Low d-c. control voltage.
Loss of motor field.
Sequence failure.
Unbalanced phase.
Overspeeding.
D-c. reverse current.
Overheating of motor windings.
Overheating of generator windings.
A-c. short circuit.
Grounding.
Overheating of machine bearings.
Sustained d-c. overcurrent.
D-c. reverse polarity.
Exciter voltage failure.

The protective equipment may be divided into two classes. The first class protects against troubles that are minor or temporary, and the operation is to shut down the machine, but restarting is permitted when the trouble has subsided.

The second class protects against troubles that are more or less injurious or permanent and the operation is to shut down and lock out the machine to prevent its further operation until inspection and

repair have been made. The source of the trouble is indicated by the operation of targets on an annunciator lockout relay which is so interlocked with the master relay as to prevent re-starting until the lockout relay has been re-set by hand.

GENERAL PRECAUTIONARY MEASURES

Experience with automatic equipment for steel mill application thus far has brought forth the following pertinent points:

The steel mill load is subject to violent fluctuations of great magnitude and duration. Because of the enormous loss that is liable to be incurred in a single failure, all apparatus used must be sturdy, of ample capacity, and absolutely reliable as proved in test and actual operation. The demand for continuity of service warrants the expense involved in applying complete protection against all exigencies. Service should never be interrupted unless absolutely necessary so that the application of short-circuit selective re-closing d-c. feeders are almost a foregone conclusion.

Because of the prevalence of gases and acid fumes which are powerful factors in the disintegration of apparatus parts, and the presence of metallic and carbonaceous particles which, because of their conductivity, interfere with the operation when deposited upon the apparatus, it is highly desirable to minimize the effect by the proper location of the substation or by the installation of washed air system of ventilation.

Periodic and proper maintenance is essential. No amount of protective equipment can forestall the troubles due to inadequate and improper maintenance. The installation of automatic equipment reduces the number of attendants, but it does not dispense with competent help.

Of recent date, automatic switching equipment for steel mill service has advanced another step in the adoption of truck-mounted breakers and steel-enclosed switches. The salient points leading to this move are safety to employees, economy in space and cost, as compared with concrete or brick structure, ease of assembly, flexibility and interchangeability. In stations where automatic and manual equipments are housed together, the truck-type breakers of both equipments, are made interchangeable. This interchangeability feature is a big step toward the prevention of costly shutdowns.

The recognition of the soundness of the argument for the application of automatic substations to the steel mill, both from the consideration of operation and economy has led to the rapid expansion and development in this Department of the electrical industry.

What Happens in Couplings; Fatigue of Materials; What It Is and How It Occurs in Flexible Couplings

Author's Correction

In the December, 1928, issue of Iron & Steel Engineer, there appeared an article entitled "What Happens in Couplings," by Prof. H. F. Moore of the University of Illinois.

Prof. Moore makes the following corrections, and we are glad to publish the corrections as follows:

On p. 515 the heading "Fallacy of Stored Energy'" is not in harmony with the statement in the text that the stored energy in a spring-type shaft coupling is real, but small in amount. "Amount of 'Stored Energy'" would be a better heading.

"On p. 514 in the title to Fig. 4A-4B the phrase "at the expense of rapid fatigue of the flexible material," is not in harmony with the statement in the text that fatigue fracture does not occur in rubber or leather as it does in metals. The phrase would be better omitted.

"On p. 515 in the title to Fig. 5A-5B the phrase "resulting in fatigue" may be taken to imply that **all** spring-type couplings will eventually fail by fatigue. Such an implication was not the intention of the author. While the design of a spring-type coupling is a matter requiring no small skill, yet if under service conditions the stresses (including intensified stresses at bearing points) are kept below the endurance limit of the metal, the coupling will withstand indefinitely long service without fatigue failure."

A. I. & S. E. E. JUNIOR DIVISION

(Devoted to practical problems of electrical department employees in the Iron and Steel Industry)

Elements of Commutation

By JERRY ALBRECHT*

FOREWORD

This data is presented as part of the Association's educational service to its Junior members. It aims to compile in the simplest possible form, some elementary facts on commutation of direct current apparatus. If it in any way helps our Junior member to increase his Electrical knowledge and his understanding of his job, it will have served its purpose.

THEORY OF COMMUTATION

To get a clear idea of the theory of commutation in direct current machines, we wish to fix the thought that direct current machines basically are alternating current machines. Windings are tapped at definite points and brought out to commutators from which current is taken off in the case of a generator or to which current is supplied in the case of a motor.

The word commutation in this sense means the changing of the alternating currents and voltages generated by the machine into direct currents and voltages.

Starting with the most elementary theory, let us take the simplest form of generator which is the alternating current type.

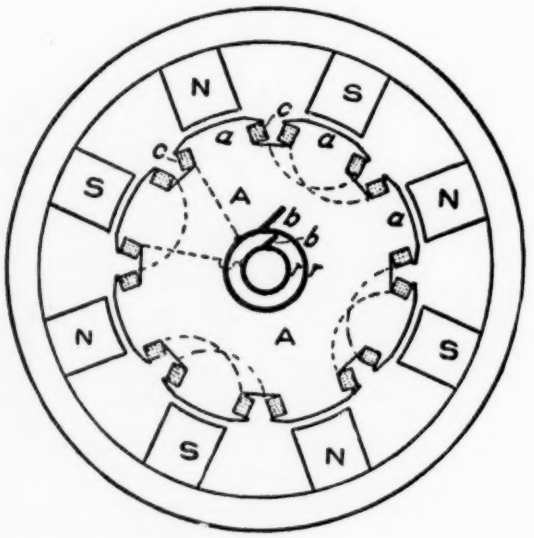


FIG. 1.

*Engineer, Pittsburgh, Pa.

In Figure 1, the frame consists of an eight pole electromagnet, with alternate north and south poles magnetized by a shunt field not shown in the sketch. The armature or rotor winding consists of a single conductor (c) wound around the rotor teeth in one direction under a north pole then across to the next tooth and around that tooth in the opposite direction under a south pole. The connections between the rotor conductors are indicated by the dotted lines. Each end of the winding is brought out to the metal slip rings (rr) mounted on the rotor shaft and insulated from each other and the shaft.

A magnetic field exists, the magnetic lines of force flowing from each north pole across the air gap through the rotor iron then to adjacent south poles hence through the frame back to the north pole.

Now as the rotor revolves, the magnetic lines of force or the flux passes through the conductor (c) in one direction when the tooth on which the coil is wound is squarely under a north pole and in the reverse direction when the tooth is squarely under a south pole.

The electromotive force or voltage which is induced or generated when a conductor cuts a magnetic field is always opposite in direction around adjacent conductors and the conductors are so connected in series that the generated voltages are added. The voltage across the slip rings (rr) is an alternating voltage which is the sum of the voltages

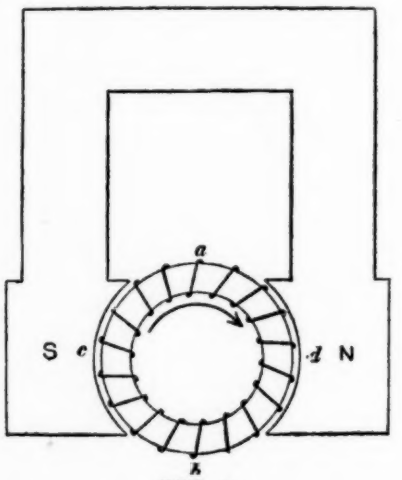


FIG. 2.

generated in each conductor. The magnitude of this voltage depends on the magnetic field strength, the number of conductors, the number of poles and the speed of the rotor.

The frequency depends on the number of pairs of poles and the speed. Thus in figure 1, which shows an eight pole machine, the frequency at 900 RPM would be $\frac{8}{2}$ x 900 or 60 cycles per second. The frequency

$$\frac{}{60}$$

per minute would be 3600 cycles which would give two (2) alternations per cycle or 7200 alternations per minute.

To more clearly illustrate the thought stated in our opening paragraph, we will refer to figure 2.

This figure shows a bipolar machine with a simple ring wound armature. N and S are the north and south poles respectively of an electromagnet, the exciting coils of which are not shown. The armature consists simply of sheet stampings wound uniformly with insulated wire as shown. As the armature revolves its conductors cut the magnetic lines flowing from the north pole of the magnet through the armature to the south pole. Voltages are generated, which, however, cannot produce currents in the closed winding inasmuch as exactly equal and opposite voltages exist on sides c and d of the ring as shown diagrammatically in figure 3 in which figure (a d b c) represents the endless winding on the ring.

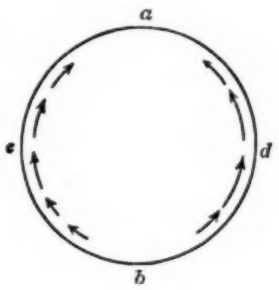


FIG. 3.

Now, if instead of being endless, the winding were opened and each end brought to an insulated slip ring, we would again have our AC Generator practically as in figure 1.

However, if the insulation on the wires of the ring winding is removed and two point of contact for carbon or metal brushes established, we now have a simple Direct current Generator. In figure 4

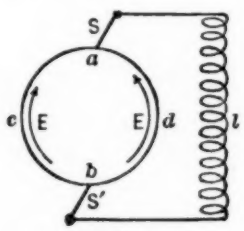


FIG. 4.

ad (AD BC) bc is again the endless winding of figure 2, S and S′ are the brushes making a sliding contact with the bare section of winding and the result is a Direct current through the external resistance. (L).

In commercial motors, leads are soldered to the various turns of wire on the ring and connected to commutator bars as shown in figure 5—

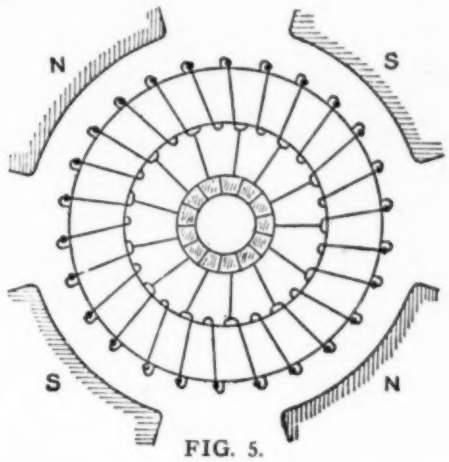


FIG. 5.

giving the old ring wound armature used extensively in the early days of the industry.

While space will not permit an extensive discussion of the various types of armature winding, we are giving in figures 7 and 7-A, 8 and 8-A diagrams showing the simplex or single lap winding and the simplex or single wave winding:

The essential difference between these two types of simplex windings should be apparent at once. In the lap winding, there are as many paths between brushes as there are pairs of field poles, while, in the wave winding, there are only two paths between brushes whatever the number of field poles may be.

Having outlined roughly the method of generating the voltages, we will now consider just what happens when an armature coil is passing through the commutation point.

In figure 6 we again show a ring wound armature. We assume the Machine is being driven and that it is acting as a Generator. The rotation is clock wise. The dotted line is the mechanical neutral that is, it is the midpoint between the North pole of the field and the adjacent South pole to the left. The coil V is undergoing commutation as its corresponding commutator segments e and f are

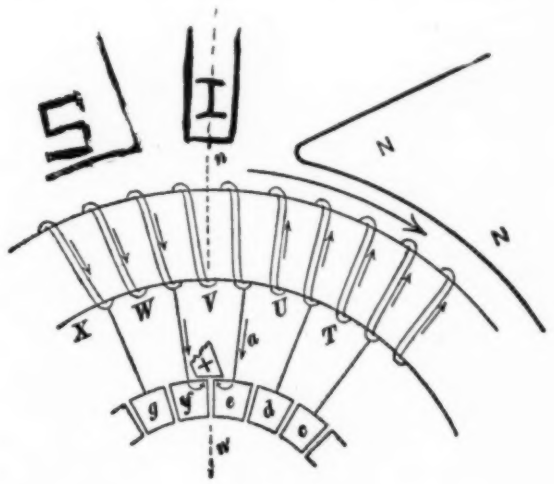


FIG. 6.

short circuited by the positive brush. Up to this point the current in Coil V has the same direction

as in coil W. It has now reached the midpoint NN' in the main magnetic field supplied by the main field poles N and S. At this midpoint or neutral point, the main magnetic field is weakest and the voltage due to this field drops practically to zero. The current in the coil must now drop to zero and be built up in the opposite direction as the commutator segments pass out from under the Brush.

So far, commutation has appeared to be a very simple process as we have considered only the effeet, on the coil, of the main field flux produced by the poles N and S, which is at its lowest value. Consider now, that the armature itself is an electromagnet, as it is an iron structure surrounded by wires (its own conductors) which are carrying current.

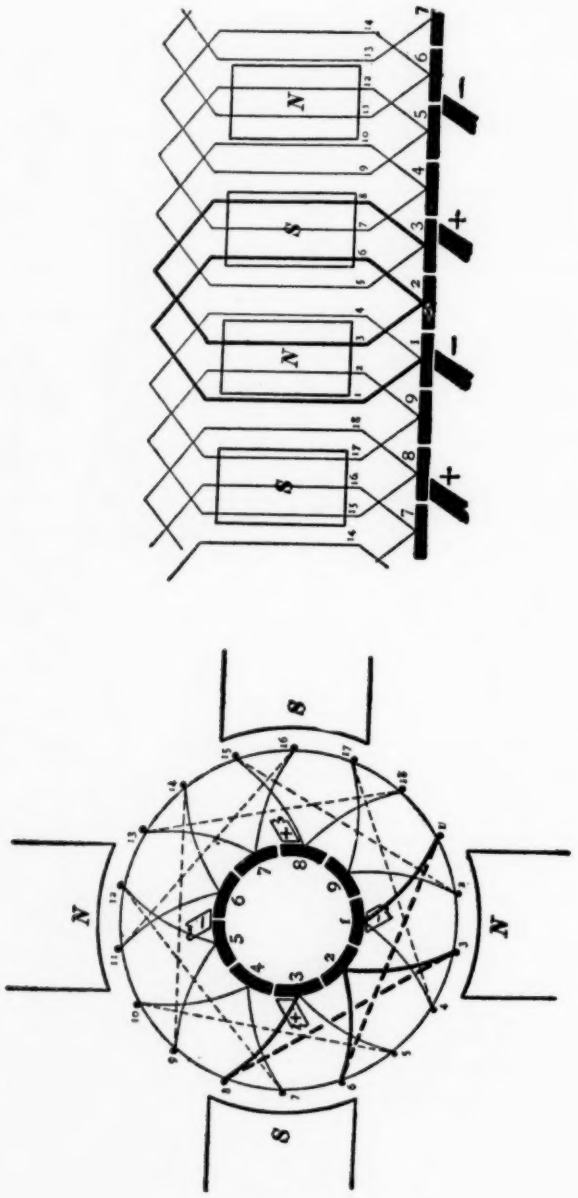


FIG. 7.

The armature winding, when carrying current, therefore always tends to set up a magnetic field, through which the armature conductors rotate and generate EMF's, just as when they cut the main field set up by the field windings. The coils, which short circuited by the brushes, also generate EMF's, and as their terminals, which are commutator bars, are connected together or short circuited by the brushes on the commutator, the EMF's generated by cutting the armature flux tend to cause local or short circuit currents to flow in such coils. Such currents will be known hereafter as the local or short circuit currents, to distinguish them from the useful or work currents of the armature.

As an armature coil carrying current in a given direction, approaches and passes under the brush, the current should die down to zero value at the midpoint of the brush and should rise to full value in the opposite direction by the time the coil leaves the brush. This would be a theoretically perfect condition, but is very difficult or almost impossible to attain in practice. The coil, while under the brush, has an EMF generated in it due to cutting the armature field, as already described, and a local current circulates. This short circuit current normally adds to that of the work current before reversal, and thus tends to maintain it right up to the moment that the coil passes out from under the brush. The reversal of the current in the short circuited coil is thus accomplished almost instantaneously instead of gradually. If, however, this local current could be generated in the opposite direction, then it would tend to oppose the work current as the coil came under the brush, so that the resultant current would first die to zero and then rise in the opposite direction, if the short circuit current were just large enough, so that the work current would simply replace the short circuit current in direction and value as the coil passes out from under the brush. Therefore, if the short circuit current were exactly the right value, the resultant effect would be the same as if the work current alone were present and this current died down to zero value as the coil passed the middle of the brush, and rose to full value in the opposite direction by the time the coil left the brush. In other words, a local current of the proper direction and value in the commutated coils will give theoretically ideal commutation. Such local current therefore, might be designated as the commutating current. In practice, it is found, however, that a current somewhat higher than the ideal value gives the general results as will be explained later. In any case, however, this local current, to be effective, must be in the reverse direction to that which would normally be set up by the armature coil cutting the magnetic field due to the armature winding itself. This means therefore, that where commutation is accomplished by means of short circuit or local currents, an external field in the opposite direction to the armature field is necessary for setting up such local currents. This result may be accomplished in several ways. The brush may be rocked forward or backward until the commutated coil comes under the magnetic field, or fringe of the field, set up by the main field winding. If rocked in one direction (forward in the generator, backward in the motor) the direction of the main field will be in opposition to the armature field. Obviously, if shifted into a strong enough external field, the armature field may be completely neutralized at some given point, such as that of the short circuited coil, or the resultant field might be even strong enough in the opposite direction to set up the de-

sired local or short circuit current in the commutated coil. Under this condition, ideal commutating conditions should be obtained. However, as the armature magnetic field at this point tends to vary with the armature current, while the external field tends to remain constant, it is evident that the ideal resultant field will only obtain at one particular load.

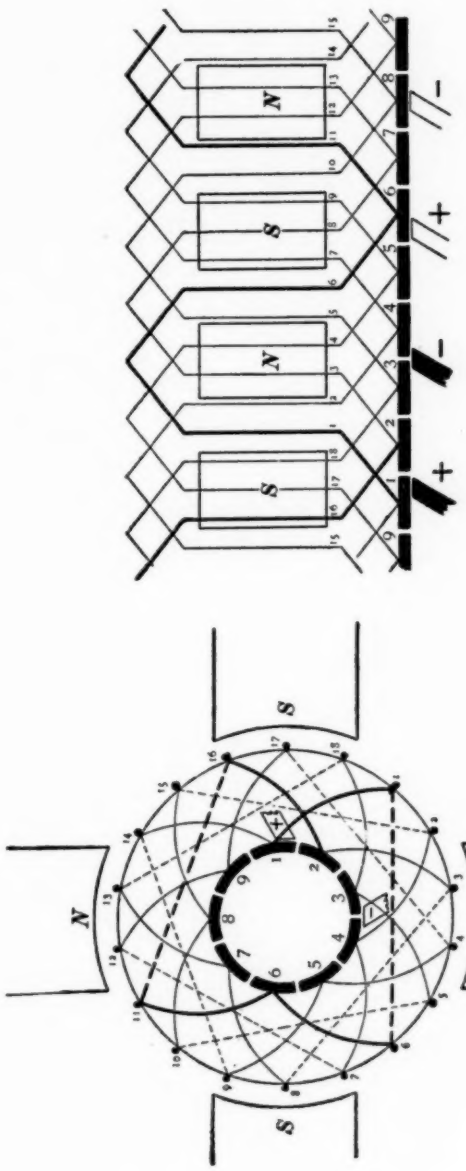


FIG. 8.

Therefore, only an average condition can be obtained in this way. However, by shifting the brushes backward or forward under the external field, the proper local or commutating currents should be obtained for any given load, but brush shifting is not usually considered a very practical method of operation, although required by many non-commutating pole machines in service. What is needed is an external field directly over the commutated coils which is always of the proper strength to set up commutating currents of the right direction and of the proper value with respect to the work currents, so that the result in the short circuited coil will give the effect of the work current reversing at the middle of the brush at all loads. To accomplish this, an external field to produce this local current should always be in opposition to the armature magnetic field, should be somewhat greater in value, and should vary in proportion to the armature field—that is, to the armature current. This result is accommplished by the now well-known commutating pole, which is simply a small pole placed over the commutated coil, and usually excited by a winding directly in series with the armature, but having a somewhat greater magnetizing force than the armature winding. The function of this pole is solely to set up in the armature coil a local or commutating current of the proper direction and value. The interpole or commutating pole would be located as shown at I in figure 6.

The Carbon Brush

It must be borne in mind that the Carbon Brush must not only carry the work currents but, also the local currents. In failing to take this into account will often times result in working the brushes at current densities which are beyond their range. Figure 9 will illustrate graphically this effect. From the figure, it will be noted that the local currents first oppose and then add to the load or work currents. This is often responsible for the brush burning or pitting at the one edge and sometimes over the whole surface.

If the reader has some understanding of the foregoing paragraphs he will realize at once that the Carbon Brush or its equivalent is essential in obtaining results as outlined. In fact, without it, the direct current industry could hardly exist. Its high resistance, its current carrying properties, its high contact drop, the refractory properties which enable it to withstand sparking, its mechanical strength and long life make it the ideal material for the purpose to which it is applied.

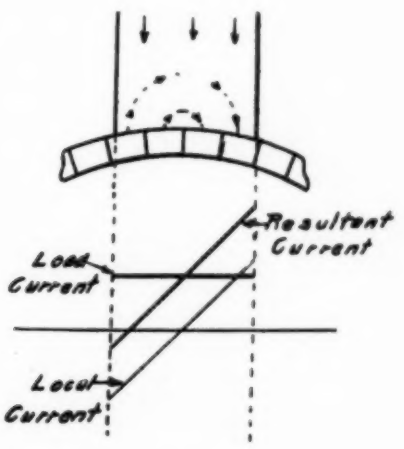


FIG. 9.

POTENTIAL CURVE UNDER THE BRUSH

A Potential Curve taken by reading the voltage drop between a Brush Holder and a number of points on the commutator under the brush face is one of the most valuable tests which can be made to determine the effect of the commutating poles on the armature coils at the instant of commutation. The set up should be made as per sketch shown in figure 10. A low reading voltmeter should be used

with one side connected to the brush box as shown, while the other side of the volt meter is attached to a contact point with which readings are taken preferably at four points on the commutator under the brush face. On machines with a large number of brushes per arm, a wooden dummy brush can be used with holes drilled in at four points through which are thrust leads from lead pencils or some other conductor, so that they make contact. For ordinary purposes, however, an Operator with a fairly steady hand can take this curve successfully by simply placing a copper point against the end of the commutator bars at the approximate points under the brush face. While this is a rather rough method, with a little practice, a fairly decent curve can be obtained. Figure 10 shows three typical curves. Curve C, which shows a rising curve indicates usually that the machine is under compensated or that the commutating pole field is too weak. Curve B showing a decreasing potential, indicates over compensation or a commutating field which is too strong. Curve A shows a curve which reverses. If this curve is obtained, polarity of the readings should be carefully checked to show whether the curve rises or drops. To do this, first check the polarity of the Brush Holders, then, in case of a Generator, if the positive terminal of the Volt Meter is held on the commutator under the positive brush and the negative terminal is held on the Brush Holder, a positive reading on the meter shows the drop to be plus, conversely, a reversed reading on the Meter shows the drop to be minus. In the case of a Motor, as the current is coming into the machine at the positive brush instead of leaving, the meter terminals are reversed from above. The procedure under the negative brush in each case is to reverse the volt meter points from that used in the positive brush. In ordinary service, the drooping polarity Curve B as shown in figure 10 is the best curve. The machine at normal loads should be slightly over compensated to take care of the saturation of the commutating poles at the maximum over loads.

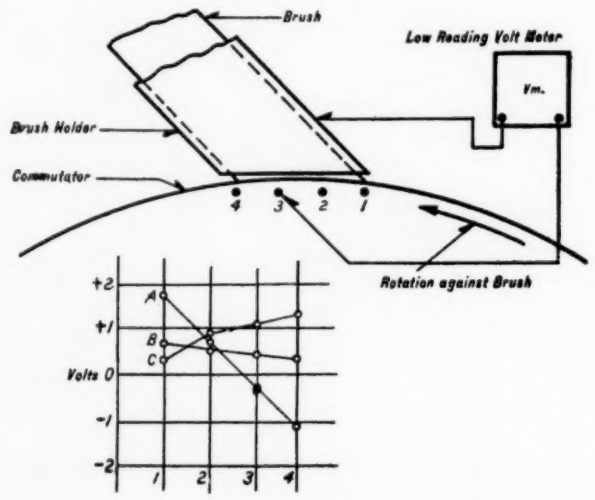


FIG. 10.

Practically the only methods of changing interpole field strengths which are open to the Operator are to either change the Air Gap by varying the shims between the pole face and the frame or by shunting the current in or out of the interpole coil. In applying a shunt to an interpole field, it should be borne in mind that the interpole field coils are inductive and, therefore, some inductance should be provided in the shunt. If this is not taken into consideration, sharp over load peaks will take the path of lowest resistance which is through the relatively low inductance of the shunt rather than through the more highly inductive circuit of the interpole field coil. This would result in a less effective field under peak loads where it is generally more essential that the commutator field be effective. Where the Operators suspects that the strength of the interpole field is not right it is best to determine by means of a german silver shunt; first, whether the field should be strengthened or weakened and then the desired effect should be permanently obtained by changing the Air Gap.

On Variable Speed Motors, with high speed ranges such as 3:1 and 4:1 over compensation is often responsible for instability at high speeds. The main field strength is very weak at the high speeds and a very strong interpole field may tend to still further weaken this field with a result that the motor speed may tend to shift back and forth along the rather steep portion of the speed curve. This is very dangerous and should be borne in mind when attempting to vary the interpole strengths of the motors mentioned.

Classification of Carbon Brushes

Carbon.
Carbon Graphite.
Electrographitized Carbon Graphite.
Metal Graphite.

Carbon Series

This series is better known to the Industry as **Plain or Simple** Carbon Brushes which are the simplest and cheapest grades. Ordinarily, the basis of these brushes is petroleum coke or gas retort coke and they usually contain no graphite and the manufacturing process does not extend beyond the carbonizing furnace. The material is quite hard and brittle with relatively low carrying capacity. It is used almost exclusively for extruded sections or molded brushes for very cheap service.

Carbon Graphite Series

This series of material employs varying proportions of Graphite in the mix and the temperature in the furnace is not sufficiently high to graphitize the plate. By varying the proportions of the mix and the temperature of the furnace, a fairly wide range of product can be obtained. This series is quite valuable to the Industry as it covers a fairly wide range of applications at a moderate price. Some limitations ordinarily are its comparatively low carrying capacity and its inability to take high to peripheral speed.

Electro Graphitic Series

This series has probably the widest application of any series. It is carried through the Electro Graphitizing Furnace and by varying the mix and temperature of the furnace a very wide range of product can be obtained. With fairly low furnace temperature, brushes with fair current carrying capacity can be obtained together with ability to take care of fairly high speeds and by retaining a certain proportion of the ash, some cleaning action can be

CARBON BRUSHES

MATERIALS AND MANUFACTURING PROCESSES

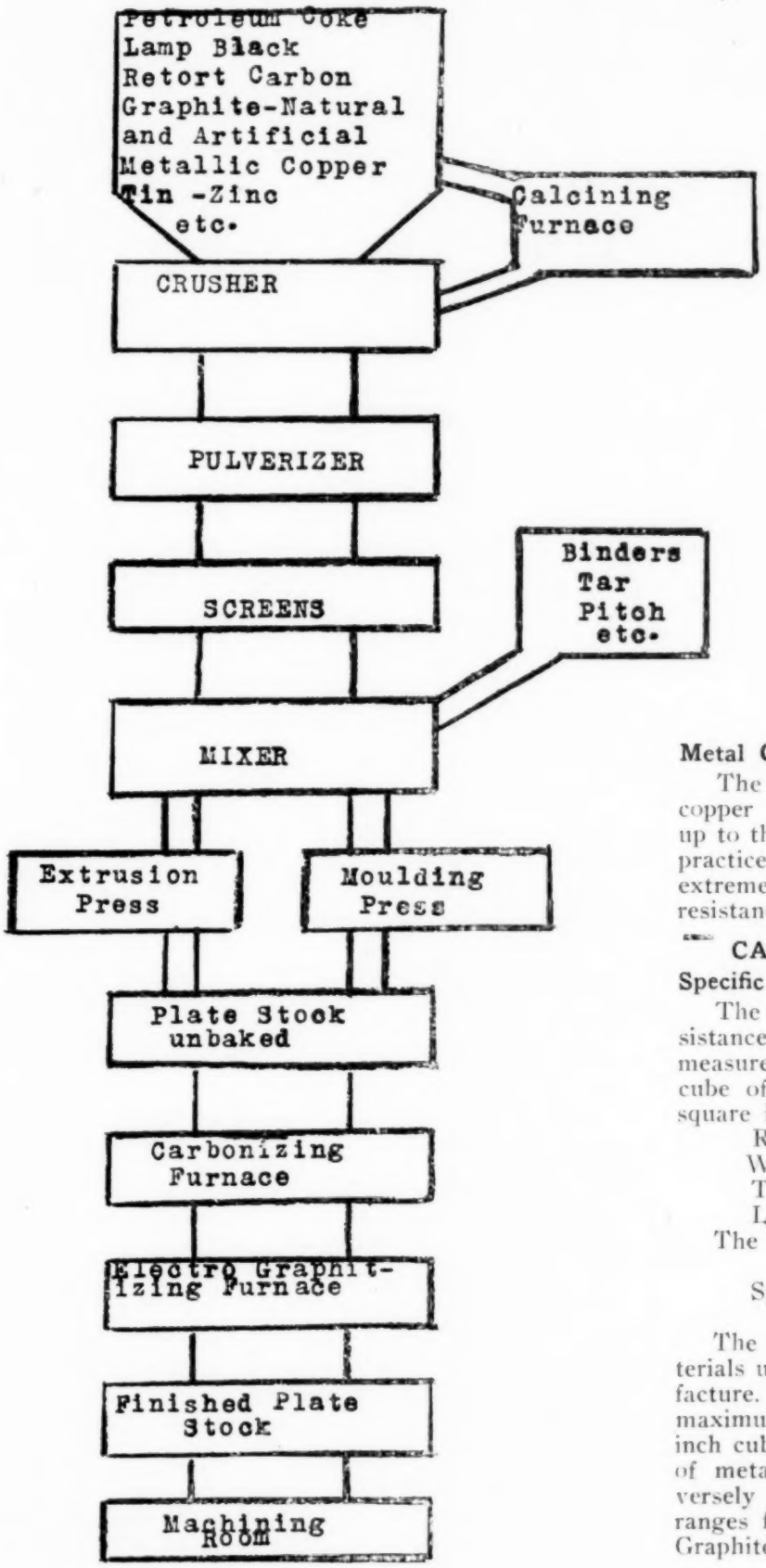


FIG. 11.

obtained which is of extreme importance on certain types of machines which do not otherwise commutate perfectly. By raising the temperatures of the Electro Graphitizing Furnace, it is possible to eliminate all abrasive material and obtain a brush which will have high contact drop, excellent carrying capacity and which will commutate modern high speed machines without excessive commutator wear.

Graphite Series

The basic material in this series is almost entirely Graphite in either its natural or its artificial form. These Brushes will carry very high currents and take very high commutator speeds. They are used mostly on special applications which are beyond the range of the high grade Electro Graphite series. Another extremely valuable feature, is the extremely high ratio of cross resistance to longitudinal resistance which can be obtained by stratification and use of special binders such as Bakelite, etc. This type is very valuable on old style machines where the induced voltage between bars at the point of commutation is very high. In spite of the low friction and low abrasion in this material, these Graphite Brushes invariably wear the commutators showing the characteristic, graphite wave after extended use. The fundamental objection is the very high price of this grade.

Metal Graphite Series

The basic material of this series is finally divided copper mixed with Graphite in varying proportions up to the maximum of about 90% copper in ordinary practice. The outstanding characteristics are the extremely high carrying capacity and low contact resistance.

CARBON BRUSH CHARACTERISTICS

Specific Resistance

The Specific Resistance of a Brush is the resistance of its material in ohms per inch cube as measured from one face to the opposite face of a cube of the brush material 1" in length and of 1 square inch cross section. If

R = Total resistance of brush
W = Width of brush in inches
T = Thickness of brush in inches
L = Length of brush in inches

The following relation exists:

$$\text{Specific Resistance} = \frac{R \times W \times T}{L}$$

The resistance of brushes depends upon the materials used and the process employed in their manufacture. Carbon and graphite brushes vary from a maximum resistance of approximately .004 ohms per inch cube to as low as .0001. The specific resistance of metal-graphite composition brushes changes inversely as the percentage of metal content and ranges from .001 to as low as .000002. Carbon and Graphite, unlike metals and most substances, have

negative resistance co-efficient meaning that as the brush heats up its resistance decreases. The importance of the factor of specific resistance is sometimes over estimated due to the fact that a very great percentage of the resistance from the pigtail to the commutator is in the contact resistance where the brush face rests on the commutator. A brush with high specific resistance has a slight tendency to reduce short circuit currents in the brush face but this advantage is usually more than off set by an undesirable heat loss in the length of the brush itself.

Carrying Capacity

Carrying capacity in amperes per square inch is the actual load current per square inch of cross section that a brush can carry without injurious heating, under normal operating conditions on a machine of average design. To calculate the current density in amperes per square inch of brush section, the following formula may be used. If

A = Load current of machine in amperes
N = Total number of brushes per machine
W = Width of brush in inches
T = Thickness of brush in inches

$$\text{Current Density in Amperes per square inch} = \frac{A}{\frac{1}{2} N \times W \times T}$$

For Slip Ring work where A is the current per ing and N the number of brushes per ring, the formula will change to

$$\text{Current Density in Amperes per square inch} = \frac{A}{N \times W \times T}$$

The approximate current per ring on the A.C. side of the Rotary Converters may be calculated by the following rules:

Single Phase, Current per ring = 1½ x Current on D.C. Side
Two Phase, Current per ring = ¾ x Current on D.C. Side
Three Phase, Current per ring = 1 x Current on D.C. Side
Six Phase, Current per ring = ½ x Current on D.C. Side.

As outlined in a previous paragraph in addition to the above, brush loading and the carrying capacity of the brush is also governed by the magnitude of the short circuit currents. For this reason, a brush should not be really worked up to its limit based on load currents alone.

Peripheral Speed

The maximum permissable speed of contact surface under brush varies considerable with the several grades. To find the peripheral speed of commutator or rings use the following formula. If

D = Diameter of Commutator or ring in inches
S = Speed of Commutator or ring in revolutions per minute

Peripheral Speed in feet per minute .262 x D x S.

The figures in table should not be exceeded under average operating conditions on commutating machines. Increased friction, chattering and chipping of brushes may result. Undercutting of commutator mica ordinarily improves operation at high speed and is constantly gaining in favor. Pure Graphite and Electro-graphite carbons are preferred for high speed work. On slip ring service the speeds shown may be increased from twenty to fifty per cent.

Contact Drop

Contact Drop is the voltage drop between brush and commutator or ring under operating conditions. It is the result of a contact resistance existing at that point. A brush is usually considered as having a very high contact drop when the total contact drop for a positive plus a negative brush runs approximately 2½ volts, and as having a very low contact drop when the same figure falls to .3 of a volt. The various grades of material will usually have contact drops lying between these two figures. This factor has a much greater influence on commutation than the specific resistance of the brush. On old style, non-interpole machines, a high contact drop is absolutely essential on account of the high short circuit currents encountered. On most modern interpole machines, brushes with low contact drop are usually satisfactory.

Coefficient of Friction

Friction is that force which opposes the motion of one body upon another and the coefficient of friction is the ratio between the force of friction and the normal pressure at the surfaces. The coefficient of friction ranges from .05 to .3 under ordinary operating conditions. This factor as well as the contact drop is extremely difficult to measure and is usually classified as high, medium and low. The coefficient of friction should not be confused with the abrasive action although abrasive action usually means friction. However, with certain grades of material, a brush may have a fairly low friction and still have considerable abrasive effect or cleaning action. By using a low friction brush the advantages usually are better efficiencies, that is, smaller friction losses, lower commutator temperatures and less wear both on the commutator and brush.

Abrasiveness

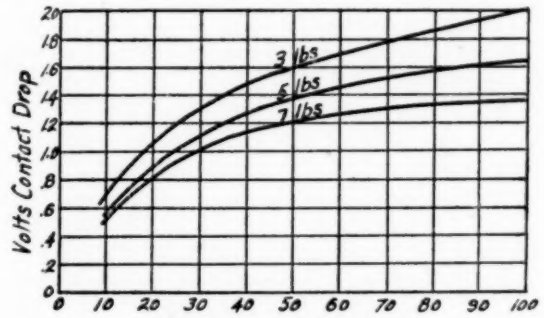
This factor is often referred to as the cleaning action and is of great importance as it most directly effects the life of the commutators and rings. The degree of abrasiveness cannot be measured in absolute figures and is again classified in general terms as high, medium and low.

This factor depends almost entirely upon the purity of the raw materials used in the manufacture of the brush. Silica and Iron are the usual impurities which remain in the form of an abrasive ash after the material has gone through the furnace. High furnace temperatures such as used in the better grade Electro-graphitized brushes will practically entirely eliminate the ash. The best grade Pure Graphite Brushes will sometimes have considerable cleaning action due to impurities which often occur in even the most carefully selected graphites. In addition, Graphite brushes sometimes show a characteristic waving of the commutator which is hard to explain but which actually occurs in practice after long periods of service. To eliminate the effects of severe sparking it is often necessary to

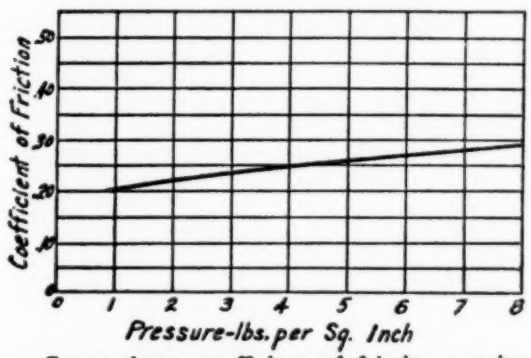
use a highly abrasive brush. In these cases of course, the commutator life must be sacrificed.

Spring Pressure

While ordinarily this should be classified as an adjustment rather than as a brush characteristic, it is usually shown in the manufacturer's tabulations and for that reason is mentioned here. The spring pressure should always be carefully checked by means of a spring balance pulling against the spring straight away from the brush. The tension on the scale when the spring begins to lift is the approximate total brush pressure. As the manufacturers figure is usually given in pounds per square inch, the total pressure indicated by the spring balance must be divided by the area of the brush in square inches. For leading or trailing brushes allowance must be made for the angle of the brush. In practice the lightest possible pressure consistent with good commutation should be used. This would cut down both brush and commutator wear, if other factors remained unchanged. However increased spring pressures mean lower contact drops and the increase in friction losses must be balanced against decrease in contact losses.



Curve shows total contact drop of positive plus negative brushes, varying with current.
Temperature during test: 75° C.
Speed during test: 2500 ft. per minute.
Pressure: 3, 5 and 7 lbs. per sq. inch.



Curve shows coefficient of friction varying with pressure.
Resistance per 1 inch cube: .0010 ohms.
Scleroscope hardness: 45.
Breaking strength: 2730 lbs. per sq. inch.
Recommended amperes per sq. inch: Commutators, 50; slip rings, 60.
Recommended maximum speed: 4000 ft. per minute.

Curve of electrographitized carbon.

FIG. 12.

Hardness

This factor is often given undue importance. The Operator will often state that a brush is too hard or too soft when he has some entirely different characteristic in mind. There is no absolute unit of hardness except that given by standard scleroscopes which measure the height of the rebound of a steel weight after it has been dropped from a fixed height to the carbon surface. Scleroscope readings of from 5 to 60 are ordinarily obtained. Hardness has absolutely no relation to abrasiveness as is often times assumed. In checking various grades of material in the scleroscope it must be borne in mind that the preparation of the surface very widely effects the scleroscope readings. Hardness is only of importance as it effects the strength of the material.

PRACTICAL CONSIDERATIONS

Checking the Neutral

(This subject has been covered in detail in the December, 1928, Issue of the Iron & Steel Engineer.)

On old line non-interpole machines except on reversing motors, the neutral point on the commutator is not of extreme importance since the brushes are usually shifted forward in case of a Generator, and backward in case of a Motor to get the most satisfactory point of commutation. On interpole machines, it is essential that the brushes be located at the neutral point.

A neutral can often be located rather easily by tracing out the windings. First, pick the coil which is located in the central point under an interpole face and then, trace it through the end windings to its commutator bars.

It is sometimes practical to check the neutral by the volt meter kick method. After the neutral has been roughly located a fairly low reading volt meter is connected across from the positive to the negative brush holders . With the motor at standstill, that is, with no current except with field current impressed on it, the brush rigging is shifted backward and forward until the volt meter shows zero kick or minimum kick as the field is flashed; that is, when the field circuit is opened and closed. The Operator should bear in mind that when the field is flashed, that is, opened or closed, high inductive voltages may be built up and a vicious arc produced at the switch.

On the manufacturer's test floor wherever practical machines are run as motors first in one direction and then in the reverse direction and the brushes are shifted until the revolutions per minute at full load are the same in either direction.

The potential curve under the brush taken as described elsewhere is very valuable in indicating the neutral. A flat curve with very low voltage readings usually indicates a correct setting.

Brush Holders

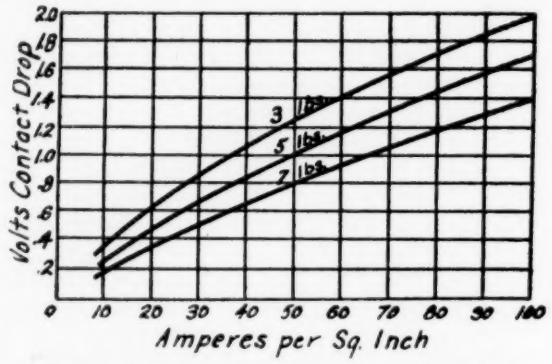
Brush Holders may be set so that the brushes bear against the commutator in either a leading, radial or trailing position. This condition ordinarily is set by the manufacturer and is beyond the control of the operator.

Improper angles often lead to chattering of the brush. The critical angle in any case is that angle at which the brush just floats in the holder that is,

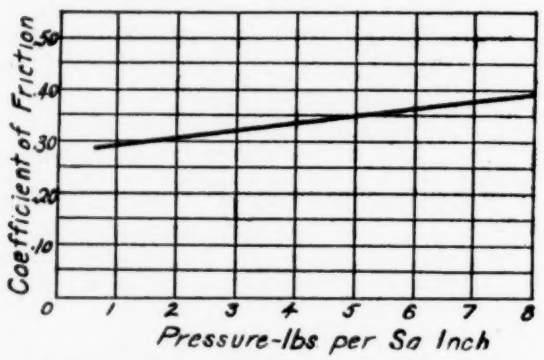
where the friction of the brush on the commutator face just balances the applied spring pressure. At this point any slight decrease or increase in the frictional force tends to throw the brush from one side to the other in the holder and the result is chattering and imperfect contact. When the chattering is serious, either, the angle must be changed or a brush with more or less friction must be used.

The brush spacing should be carefully checked at frequent intervals. The check should be made between all brush studs making sure that the line of the brushes is exactly parallel to the axis of the rotor shaft and also, that all lines of the brushes are equally spaced, from each other.

The Brush Holders should be carefully checked for wear. This should be done not only at the top of the holder but, if necessary, the holder should be removed from the machine and the bottom of the holder checked. It very often happens that the brush will apparently fit snugly in the holder at the top, while at the bottom, it is free to move an appreciable distance. Brush Holder wear is due to not only mechanical wear but also to an electrolytic action which may become quite marked. It is important to check the condition of the pigtails and terminals on the brushes as failure of a pigtail or a connection may result in severe burning of the boxes or the destruction of the pressure spring which may be called on to carry the load.



Curve shows total contact drop of positive plus negative brushes, varying with current.
Temperature during test: 75° C.
Speed during test: 2500 ft. per minute.
Pressure: 3, 5 and 7 lbs. per sq. inch.



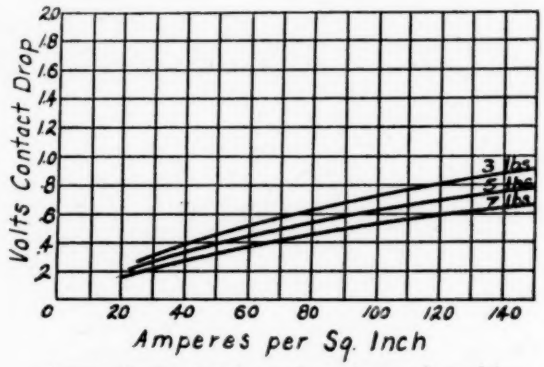
Curve shows co-efficient of friction varying with pressure.
Resistence per 1 inch cube: .00052 ohms.
Scleroscope hardness: 17.
Breaking strength: 2900 lbs. per sq. inch.
Recommended amperes per sq. inch: Commutators, 60; slip rings, 65.
Recommended maximum speed: 3500 ft. per minute.

Curve of metal graphite brush 40% copper.

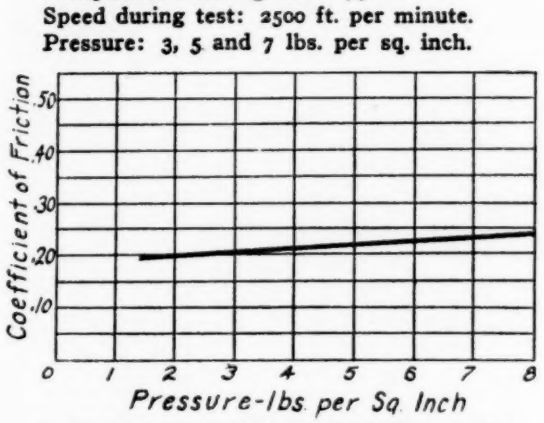
FIG. 13.

Condition of the Commutator

Commutators can be reconditioned either by cutting, grinding or stoning each of which methods has its advocates. The final result depends to some extent on the tools and methods used but principally, upon the skill of the Operator. Reconditioning a commutator should only be attempted by a skilled mechanic as the operation is entirely too delicate to be entrusted to the inexperienced worker.



Curve shows total contact drop of positive plus negative brushes, varying with current.
Temperature during test: 75° C.
Speed during test: 2500 ft. per minute.
Pressure: 3, 5 and 7 lbs. per sq. inch.



Curve shows co-efficient of friction varying with pressure.
Resistance per 1 inch cube: .000095 ohms.
Scleroscope hardness: 21.
Breaking strength: 3940 lbs. per sq. inch.
Recommended ampers per sq. inch: Commutators, 90; slip rings, 90.
Recommended maximum speed: 3500 ft. per minute.

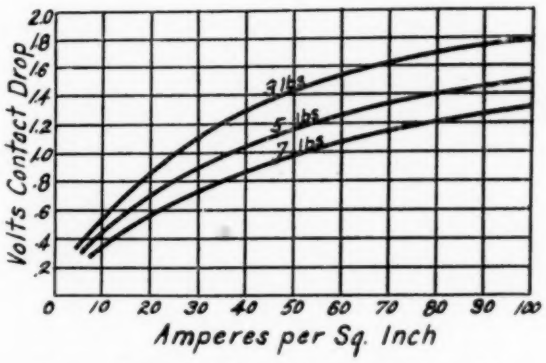
Curves of metal graphite brush 85 per cent copper.

FIG. 14.

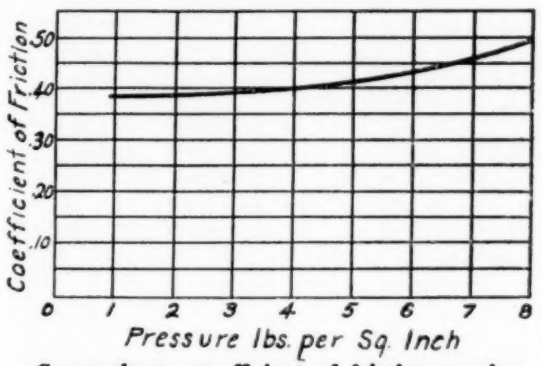
Undercutting is the general practice today and again the success of the operation depends quite largely on the skill of the Operator. The V and the U or square slot, each has its champions. After turning and undercutting, the job should be very carefully inspected to eliminate projecting slivers of mica and fins of copper at the edges of the bars. It is good practice to relieve the edges

of the bars with a fine file. The final finish or polish on a commutator should be effected with a very fine "oxidizing" stone or a maple wood block.

After the final finish has been put on a commutator and the machine put in service, it should never be sandpapered except in very special cases. Where absolutely necessary, the finest sandpaper should be used and the brushes should either be off the commutator during the process or should be removed and carefully freed from all traces of sand before the machine is again placed in operation. The grit should be removed from the slots



Curve shows total contact drop of positive plus negative brushes, varying with current.
Temperature during test: 75° C.
Speed during test: 2500 ft. per minute.
Pressure: 3, 5 and 7 lbs. per sq. inch.



Curve shows co-efficient of friction varying with pressure.
Resistance per 1 inch cube: .0010 ohms.
Scleroscope hardness: 39.
Breaking strength: 3570 lbs. per sq. inch.
Recommended current for commutator service: 40 amperes per sq. inch.
Recommended maximum speed: 3500 ft. per minute.

Curves of Low Grade Carbon-Extruded Sections.

as the presence of this grit under the brush face will surely cause trouble. The best method of wiping a commutator, is to use several turns of heavy canvas wrapped around a wooden block. A fairly heavy pressure of the block against the commutator is usually sufficient to thoroughly clean the surface. In very stubborn cases of blackened commutators, slightly moistening the canvas block with kerosene will usually be found very effective.

It is our opinion that undercutting has been carried too far, particularly as applied to slow speed Generators and Motors which operate under certain conditions. There are a large number of such applications where flush mica and a fairly abrasive carbon brush will give very satisfactory results.

Commutator Wear

Commutator wear is due to both mechanical and electrical causes. Even, without any current flowing, any carbon brush will eventually wear the commutator. When one surface slides over another, the frictional resistance must result in mechanical wear. This wear is entirely a function of the speed of the commutator, the friction of the brush and its abrasive action.

Among the electrical causes of wear, the electrolytic action is very marked. Where current leaves a brush, going to the commutator, this electrolytic effect carries off particles of the brush. Where current leaves the commutator going to the brush, the same action causes particles of copper to leave the commutator. In some grades of brushes, these particles of copper bury themselves in the face of the brush and the brush is said to "pick" copper. Under this condition, the abrasive action of the brush is increased greatly due to the spots of copper. In addition, points of low contact resistance are formed resulting in local heating, glowing and selective action of the brushes where one or several brushes tend to hog the load. On account of the Electrolytic action, brushes should always be "staggered" by pairs of poles rather than by alternate arms.

Another source of wear is the actual destruction of the commutator bars especially, at the edges due to burning action of the arcing or sparking under the brush face. Under severe sparking conditions, the commutator surface rapidly oxidizes and the high resistance film thus formed further increases the sparking. If the condition cannot be remedied by machine adjustments, the only solution is a highly abrasive brush which will scour the commutator and keep it clean. This means rapid commutator wear.

The mica in modern machines is now of such high quality that it has been practically eliminated as a source of trouble. It is still however subject to attack by oil from the bearings. Even a very small amount of oil will tend to deteriorate the mica. The presence of small particles, worn from brushes or the commutator, in the slots will result in "ring firing". The slots should be cleaned at intervals and kept free from oil.

The commutator should be kept mechanically tight. The V rings especially on large Generators should be pulled up periodically particularly when the machine is new and the commutator still not thoroughly seasoned. This should be done with the machine hot which would be just at the conclusion of a long run. Failure to take this precaution will invariably result in high commutator bars which may rise and wreck a set of brushes in a very short time. A hot commutator may often show high bars which go down as the commutator cools.

A very high polish on the commutator surface and also on the brush surface is ordinarily to be desired but at times may result in the brushes chattering. When this condition occurs a very light sandpapering of the brush surface often will cure it.

BULLETIN*

Our policy is to have this place known far and wide as a good place to work.

A place where everyone has a chance.

Where every worker is paid the highest wages that can be paid and yet leave room for the business to be successful.

To safeguard work just as far as it can be safeguarded.

To Recognize good work.

And to appreciate the helpful assistance of every co-worker.

President

*At a recent visit to the Lukens Steel Co., the editor of the Iron and Steel Engineer noticed the above bulletin and feeling that the Steel Mill Fraternity might be glad to note what other companies are doing in Bulletin Service, the above is presented.

J. F. KELLY, Editor.

Rolling Mill Statistics Year 1928

These Statistics indicate the Companies which purchased Rolling Mill Equipment during 1928. The type and style of mill, motor characterstics, method of drive and companies who furnished the main drive motors are tabulated.

Name of Plant and Location	H.P. of Motor	R.P.M.	Voltage	Cycle	Type and Style of Mill	Method of Drive	Date of Pur.	Motor Mfg. by
American Brass Co., Kenosha, Wis.	800	443	2200	60	Copper Mill	Geared	1928	A.C.
Aluminum Co. of A., Massena, N. Y.	5000	50/120	600	DC	Blooming Mill	Direct	1928	A.C.
Aluminum Co. of America, Massena, N. Y.	500	500	2200	25	Aluminum Mill	Geared	1928	G.E.
American Rolling Mill Co., Ashland, Ky.	600	585	2200	60	16" Sheet Mill	Geared	1928	W.
American Smelt. & Ref. Co., Baltimore, Md.	1200	375	440	25	Brass & Copper Mill	Geared	1928	G.E.
American Steel & Wire Co., Cleveland, O.	1200	125/275	600	DC	10" Strip Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	1000	189-½	2200	60	Wire Mill	Direct	1928	W.
Atlantic Steel Co., Atlanta, Ga.	800	425/875	250	DC	12" Hoop Mill	Direct	1928	G.E.
American Steel & Wire Co., Cleveland, O.	750	200/600	600	DC	10" Strip Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	750	200/600	600	DC	Merchant Mill	Geared	1928	W.
American Steel & Wire Co., Cleveland, O.	600	205/515	600	DC	Merchant Mill	Geared	1928	W.
American Steel & Wire Co., Cleveland, O.	600	205/515	600	DC	Merchant Mill	Geared	1928	W.
American Steel & Wire Co., Cleveland, O.	500	543/892	600	DC	10" Strip Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	500	667/1000	600	DC	10" Strip Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	500	250/380	600	DC	10" Strip Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	500	340/543	600	DC	10" Strip Mill	Direct	1928	W.
American Smelt. & Ref. Co., Baltimore, Md.	500	375/750	440	25	Copper Sheet Mill	Geared	1928	G.E.
American Steel & Wire Co., Cleveland, O.	500	435/722	600	DC	10" Strip Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	400	180/540	600	DC	Merchant Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	400	223/669	600	DC	Merchant Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	400	250/750	600	DC	Merchant Mill	Direct	1928	W.
American Steel & Wire Co., Cleveland, O.	400	295/885	600	DC	Merchant Mill	Direct	1928	W.
Barton Spider Web. Co., Chicago, Ill.	500	150/450	230	DC	Merchant Mill	Direct	1928	W.
Barton Spider Web. Co., Chicago, Ill.	300	225/450	230	DC	Merchant Mill	Direct	1928	W.
Bethlehem Steel Co., Johnstown, Pa.	1000	292	6600	25	9" Bar Mill	Direct	1928	W.
Bourne Fuller Co., Cleveland, O.	1000	400/800	230	DC	10" Merchant Mill	Geared	1928	G.E.
Carnegie Steel Co., Youngstown, O.	800	425/875	250	DC	12" Hoop Mill	Direct	1928	W.
Carnegie Steel Co., Youngstown, O.	800	425/875	250	DC	12" Hoop Mill	Direct	1928	W.
Carnegie Steel Co., Youngstown, O.	750	225/500	250	DC	12" Hoop Mill	Direct	1928	W.
Carnegie Steel Co., Youngstown, O.	750	225/500	250	DC	12" Hoop Mill	Direct	1928	W.
Carnegie Steel Co., Youngstown, O.	600	400/900	250	DC	12" Hoop Mill	Geared	1928	W.
Carnegie Steel Co., Youngstown, O.	600	400/900	250	DC	12" Hoop Mill	Geared	1928	W.
Carnegie Steel Co., Youngstown, O.	600	400/900	250	DC	12" Hoop Mill	Geared	1928	W.
Carnegie Steel Co., Youngstown, O.	400	420/1050	250	DC	12" Hoop Mill	Geared	1928	W.
Carnegie Steel Co., Youngstown, O.	300	250/750	250	DC	12" Hoop Mill	Geared	1928	W.
Chase Companies, Inc., Waterville, Conn.	500	450	2300	60	Brass Mill	Geared	1928	G.E.
Chase Companies, Inc., Waterville, Conn.	400	600	2300	60	Brass Mill	Geared	1928	G.E.
Chase Companies, Inc., Waterville, Conn.	400	600	2300	60	Brass Mill	Geared	1928	G.E.
Carpenter Steel Co., Reading, Pa.	400	400	2200	60	9" Merchant Mill	Belted	1928	G.E.
Central Alloy Steel Corp., Canton, O.	500	353	2200	60		Geared	1928	A.C.
Columbia Steel Co., Pittsburgh, Cal.	500	240	2200	60	Cold Roll Mill	Geared	1928	W.
Columbia Steel Co., Pittsburgh, Cal.	5000	82	2200	60	21" Con. Bar and Billet Mill	Direct	1928	W.
Columbia Steel Co., Pittsburgh, Cal.	5000	82	2200	60	21" Con. Bar and Billet Mill	Direct	1928	W.
Columbia Steel Co., Pittsburgh, Cal.	1800	252	2200	60	Hot Tin Mill	Geared	1928	W.
Columbia Steel Co., Pittsburgh, Cal.	1000	235	2200	60	Cold Tin Mill	Geared	1928	W.
Dallas Brass & Copper Co., Chicago, Ill.	400	300	440	60	Copper & Brass Rolling Mill	Geared	1928	E.M.
Dallas Brass & Copper Co., Chicago, Ill.	300	514	440	60	Copper & Brass Rolling Mill	Geared	1928	E.M.
Danville Structural Steel Co., Danville, Ky.	2000	200	2200	60	Rail Rerolling Mill	Direct	1928	W.
Danville Structural Steel Co., Danville, Ky.	1500	164	2200	60	Hot Strip Mill	Direct	1928	E.M.
Danville Structural Steel Co., Danville, Ky.	1500	164	2200	60	Hot Strip Mill	Direct	1928	E.M.
Danville Structural Steel Co., Danville, Ky.	1000	875	2200	60	Rail Rerolling Mill	Geared	1928	W.
Globe Steel Tube Co., Milwaukee, Wisc.	1200	112/5	2200	60	Tube Mill	Geared	1928	A.C.
Globe Steel Tube Co., Milwaukee, Wisc.	350	720	2200	60	Tube Mill	Geared	1928	A.C.
Globe Steel Tube Co., Milwaukee, Wisc.	350	514	2200	60	Tube Mill	Geared	1928	A.C.
Globe Steel Tube Co., Milwaukee, Wisc.	350	720	2200	60	Tube Mill	Geared	1928	A.C.
Globe Steel Tube Co., Milwaukee, Wisc.	350	514	2200	60	Tube Mill	Geared	1928	A.C.
Gulf States Steel Co., Alabama City, Ala.	2100	720	6600	60	Rod Mill	Geared	1928	W.
Gulf States Steel Co., Alabama City, Ala.	2750	450	6600	60	Rod Mill	Geared	1928	W.
Gulf States Steel Co., Alabama City, Ala.	1750	514	6600	60	Rod Mill	Geared	1928	W.
Gulf States Steel Co., Alabama City, Ala.	1750	180	6600	60	Rod Mill	Direct	1928	W.
Gulf States Steel Co., Alabama City, Ala.	1200	520/575	230	DC	Rod Mill	Direct	1928	W.
Gulf States Steel Co., Alabama City, Ala.	1300	257	6600	60	Rod Mill	Direct	1928	W.
Gulf States Steel Co., Alabama City, Ala.	450	720	2200	60	Wire Bench Mill	Geared	1928	W.
Gulf States Steel Co., Alabama City, Ala.	450	720	2200	60	Wire Bench Mill	Geared	1928	W.
Gulf States Steel Co., Alabama City, Ala.	450	720	2200	60	Wire Bench Mill	Geared	1928	W.
Hoskins Mfg. Co., Detroit, Mich.	400	277	440	60	Chromel Mill	Direct	1928	W.
Illinois Steel Co., S. Chicago, Ill.	6000	75/140	750	DC	28" Structural Mill	Direct	1928	G.E.
Illinois Steel Co., S. Chicago, Ill.	7000	50/120	750	DC	40" Blooming Mill	Direct	1928	G.E.
Illinois Steel Co., S. Chicago, Ill.	3500	50/120	750	DC	32" Structural Mill	Direct	1928	G.E.
Interstate I. & S. Co., Chicago, Ill.	2500	80	2200	60	Bar Mill	Direct	1928	A.C.
J. A. Roebling Sons Co., Trenton, N. J.	2500	180/450	600	DC	Wire Rod Mill	Geared	1928	G.E.
J. A. Roebling Sons Co., Trenton, N. J.	2000	295	2200	60	Billet Mill	Geared	1928	G.E.
J. A. Roebling Sons Co., Trenton, N. J.	800	469/750	600	DC	Wire Rod Mill	Geared	1928	W.
J. A. Roebling Sons Co., Trenton, N. J.	800	469/750	600	DC	Wire Rod Mill	Geared	1928	G.E.
J. A. Roebling Sons Co., Trenton, N. J.	600	350/700	600	DC	Wire Rod Mill	Geared	1928	G.E.
Jones & Laughlin Steel Co., Woodlawn, Pa.	2000	250	6600	25	Tube & Piercing Mill	Geared	1928	G.E.
Jones & Laughlin Steel Co., Woodlawn, Pa.	1000	375	6600	25	Tube Mill	Geared	1928	G.E.
Jones & Laughlin Steel Co., Woodlawn, Pa.	400	500	6600	25	Reducing Tube Mill	Geared	1928	G.E.
Jones & Laughlin Steel Co., Woodlawn, Pa.	400	500	6600	25	Reducing Tube Mill	Geared	1928	G.E.
Jones & Laughlin Steel Co., Woodlawn, Pa.	350	275/550	230	DC	Tube Reeling Mill	Geared	1928	G.E.
Jones & Laughlin Steel Co., Woodlawn, Pa.	350	275/550	230	DC	Tube Reeling Mill	Geared	1928	G.E.
Kalman Steel Co., Blasdell, N. Y.	300	500	220	25	Slitting Mill	Geared	1928	G.E.
Keystone Steel & Wire Co., Peoria, Ill.	500-340	588-400	2200	60	Rod Mill	Geared	1928	W.
Kilby Car & Fdry. Co., Anniston, Ala.	600	720	2200	60	18" Breakdown Mill	Geared	1928	G.E.
Laclede Steel Co., Madison, Ill.	800	300	2300	60	10" Merchant Mill	Geared	1928	G.E.
Laclede Steel Co., Alton, Ill.	350	400/800	230	DC	8" Merchant Mill	Direct	1928	G.E.
National Tube Co., Gary, Ind.	1500	200/500	600	DC	Seamless Tube Mill	Direct	1928	A.C.
National Tube Co., Gary, Ind.	1500	200/500	600	DC	Seamless Tube Mill	Direct	1928	A.C.
National Tube Co., McKeesport, Pa.	1500	250/565	600	DC	13" Skelp Mill	Direct	1928	G.E.
National Tube Co., McKeesport, Pa.	1500	315/630	600	DC	13" Skelp Mill	Direct	1928	G.E.
National Tube Co., McKeesport, Pa.	1000	145/327	600	DC	13" Skelp Mill	Direct	1928	G.E.
National Tube Co., McKeesport, Pa.	1000	190/427	600	DC	13" Skelp Mill	Direct	1928	G.E.
National Tube Co., McKeesport, Pa.	800	350/790	600	DC	13" Skelp Mill	Geared	1928	G.E.
National Tube Co., McKeesport, Pa.	800	350/790	600	DC	13" Skelp Mill	Geared	1928	G.E.

Name of Plant and Location	H.P. of Motor	R.P.M.	Voltage	Cycle	Type and Style of Mill	Method of Drive	Date of Pur.	Motor Mfg. by
Newton Steel Co., Newton Falls, O.	400	350	2200	60	Cold Roll Mill	Geared	1928	W.
Newton Steel Co., Newton Falls, O.	400	350	2200	60	Cold Roll Mill	Geared	1928	W.
Newton Steel Co., Newton Falls, O.	400	350	2200	60	Cold Roll Mill	Geared	1928	W.
Phoenix Horseshoe Co., Joliet, Ill.	500	440	440	60	16″ Bar Mill	Chain	1928	W.
Phoenix Horseshoe Co., Joliet, Ill.	400	440	440	60	8″ Mill	Chain	1928	W.
Phoenix Horseshoe Co., Joliet, Ill.	400	440	440	60	8″ Mill	Chain	1928	W.
Phoenix Horseshoe Co., Joliet, Ill.	400	440	440	60	8″ Mill	Chain	1928	W.
Pittsburgh Steel Co., Monessen, Pa.	1800	475/550	550	DC	Merchant Mill	Direct	1928	C.W.
Pittsburgh Steel Co., Allenport, Pa.	1800	150	6600	60	Tube Mill	Geared	1928	W.
Pittsburgh Steel Co., Allenport, Pa.	350	450	2200	60	Tube Rolling Mill	Geared	1928	E.M.
Sharon Steel Hoop Co., Sharon, Pa.	4500	150/450	600	DC	Strip Mill	Geared	1928	G.E.
Sharon Steel Hoop Co., Sharon, Pa.	1250	103/253	600	DC	Strip Mill	Direct	1928	G.E.
Sharon Steel Hoop Co., Sharon, Pa.	1250	137/326	600	DC	Strip Mill	Direct	1928	G.E.
Sharon Steel Hoop Co., Sharon, Pa.	1250	175/413	600	DC	Strip Mill	Direct	1928	G.E.
Sharon Steel Hoop Co., Sharon, Pa.	1250	200/500	600	DC	Strip Mill	Direct	1928	G.E.
Sharon Steel Hoop Co., Sharon, Pa.	1250	250/580	600	DC	Strip Mill	Direct	1928	G.E.
Sharon Steel Hoop Co., Sharon, Pa.	1250	312/625	600	DC	Strip Mill	Direct	1928	G.E.
Sheffield Steel Corp., Kansas City, Mo.	2500	296	2200	60	18″ Cont. Rod Mill	Geared	1928	A.C.
Sheffield Steel Corp., Kansas City, Mo.	1500	137/275	600	DC	Rod Mill	Direct	1928	W.
Sheffield Steel Corp., Kansas City, Mo.	1500	200/600	600	DC	Rod Mill	Geared	1928	W.
Sheffield Steel Corp., Kansas City, Mo.	800	240/500	600	DC	Rod Mill	Direct	1928	W.
Steel Co. of Canada, Hamilton, Ont.	1000	450/900	600	DC	10″ Merchant Mill	Geared	1928	W.
Steel Co. of Canada, Hamilton, Ont.	600	450/900	600	DC	10″ Merchant Mill	Geared	1928	W.
Steel Co. of Canada, Hamilton, Ont.	600	450/900	600	DC	10″ Merchant Mill	Geared	1928	W.
Steel Co. of Canada, Hamilton, Ont.	500	250/500	600	DC	10″ Merchant Mill	Direct	1928	W.
Steel Co. of Canada, Hamilton, Ont.	500	150/300	600	DC	10″ Merchant Mill	Direct	1928	W.
Steel Co. of Canada, Hamilton, Ont.	500	200/400	600	DC	10″ Merchant Mill	Direct	1928	W.
Superior Steel Corp., Carnegie, Pa.	2000	180	2200	60	14″ Strip Mill	Direct	1928	W.
Superior Steel Corp., Carnegie, Pa.	2000	200/350	600	DC	14″ Strip Mill	Direct	1928	W.
Superior Steel Corp., Carnegie, Pa.	1500	325/450	600	DC	10″ Strip Mill	Direct	1928	W.
Superior Steel Corp., Carnegie, Pa.	800	450	2200	60	8″ Strip Mill	Direct	1928	W.
Superior Steel Corp., Carnegie, Pa.	500	400/600	600	DC	8″ Strip Mill	Direct	1928	W.
Timken Roller Bearing Co., Canton, O.	4000	250/465	240	DC	Piercing Mill	Geared	1928	G.E.
Timken Roller Bearing Co., Canton, O.	2000	250/465	240	DC	22″ Bar Mill	Geared	1928	G.E.
Timken Roller Bearing Co., Canton, O.	1200	300/600	230	DC	12″-9″ Merchant Mill	Geared	1928	A.C.
Timken Roller Bearing Co., Canton, O.	500	400/800	230	DC	12″-9″ Merchant Mill	Geared	1928	A.C.
Timken Roller Bearing Co., Canton, O.	1200	514	2200	60	8″ Merchant Mill	Geared	1928	G.E.
Timken Roller Bearing Co., Canton, O.	600	227/454	230	DC	12″-9″ Merchant Mill	Geared	1928	G.E.
Timken Roller Bearing Co., Canton, O.	600	600	2200	60	8″ Merchant Mill	Geared	1928	A.C.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	800	760/1050	250	DC	10″ Merchant Mill	Direct	1928	G.E.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	800	510/870	250	DC	10″ Merchant Mill	Direct	1928	C.W.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	750	360/600	250	DC	10″ Merchant Mill	Direct	1928	C.W.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	700	270/520	250	DC	10″ Merchant Mill	Direct	1928	C.W.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	600	350/788	250	DC	10″ Merchant Mill	Geared	1928	C.W.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	600	350/788	250	DC	10″ Merchant Mill	Geared	1928	C.W.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	600	350/788	250	DC	10″ Merchant Mill	Geared	1928	C.W.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	400	420/1050	250	DC	10″ Merchant Mill	Geared	1928	C.W.
Tenn. Coal Iron & R. R. Co., Fairfield, Ala.	300	250/750	250	DC	10″ Merchant Mill	Geared	1928	C.W.
Vulcan Crucible Steel Co., Aliquippa, Pa.	400	700	440	60	Merchant Mill	Geared	1928	W.
Wheeling Steel Corp., Steubenville, O.	7000	50/100	750	DC	Slabbing Mill	Direct	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	3000	200/400	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	3000	200/400	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	3000	200/400	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	3000	200/400	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	2300	200/400	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	1650	112.5/270	750	DC	Slabbing Mill	Direct	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	1500	150	6600	60	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	1500	220/440	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	1200	250/500	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	1200	250/500	600	DC	Wide Strip Mill	Geared	1928	G.E.
Wheeling Steel Corp., Steubenville, O.	900	150/300	600	DC	Wide Strip Mill	Geared	1928	G.E.
West Virginia Rail Co., Huntington, W. Va.	1000	225	2300	60	Rail Mill	Geared	1928	A.C.
West Virginia Rail Co., Huntington, W. Va.	600	885	2300	60	Rail Mill	Geared	1928	A.C.
West Virginia Rail Co., Huntington, W. Va.	500	257	2300	60	Rail Mill	Geared	1928	A.C.
Waterbury Rolling Mills, Waterbury, Conn.	600	90	440	60	Brass & Nickel Silver Rolling Mill	Direct	1928	E.M.
Weirton Steel Co., Weirton, W. Va.	500	210/525	600	DC	16″ Strip Mill	Geared	1928	G.E.
Youngstown Sheet & Tube Co., Youngstown, O.	5000	514	6600	60	18″ Billet Mill	Geared	1928	G.E.
Youngstown Sheet & Tube Co., Youngstown, O.	5000	514	6600	60	18″ Sheet Bar Mill	Geared	1928	G.E.
Youngstown Sheet & Tube Co., Youngstown, O.	7000	50/130	700	DC	40″ Blooming Mill	Direct	1928	W.
Youngstown Sheet & Tube Co., Youngstown, O.	2000	275/550	600	DC	10″ Skelp Mill	Geared	1928	G.E.

*Detailing of Welded Steel Buildings**

By E. C. BROWN†

New departures in practically every line of endeavor have inevitably met with resistance, particularly from those who are engaged in the line of work in which the departure is made and who prefer to adhere to former methods.

When the first wrought iron nail was introduced the "doubting Thomases" implored the people not to permit their use and the "powers that were" to legislate against the use of the iron nail in any structure, the plea being,—first, that the nail was not reliable except in part, when it was possible to clinch; secondly, because the elements would soon cause its deterioration and thirdly, and by no means the least objection, that lightning would surely be drawn in by these "iron pegs" and so cause destruction of life and limb; further, the old "wooden key" or "trennel" would always suffice.

Even as late as the early eighties, this "lightning bogy" was still with us when steel frame structures first began to appear.

Another objection raised was the allegation that steel was too brittle and even after steel was introduced for main members, a good many of us can

*Jones & Laughlin Steel Corporation, Pittsburgh, Pa.
†Presented before the Pittsburgh Division of the American Welding Society, January 30, 1929.

still remember the iron rivets, and it took a long time for the steel rivet to become generally acceptable.

We are now beginning to face the welded structure, which is most essentially a child of the present day and this welded structure is traveling the same thorny path of its immediate predecessor, but its advocates have the same patient determination and spirit, which spells the one word that applies to this form of structure—namely, success—that overcame the obstacles mentioned above which faced other forms of metallic construction.

You have seen this afternoon the second largest structure of the welded type in the United States and in the writer's opinion there will be many more coming in the immediate future.

The details of this structure were prepared by the writer from general plans by Bernard Prack. The steel was furnished by the Jones & Laughlin Steel Corporation and the field welding and erection was done by Minnotte Brothers Company.

In the detailing of this work there were many points developed, some of which may be interesting. The main material was ordered, cut to length and shipped direct from the mill to the job. This material had the usual mill variations and was marked with an item number on each piece for identification in the field, and in addition, the detailed material that had Shop work, such as base plates, base angles and connections were also given an assembly mark.

The fitters on the job assembled and clamped this material together from the Shop Bills and Detail Drawings, after which the ground welding was done. Column slabs, where light, were welded to the column shaft prior to erection. The heavier slabs were welded to the columns after erection. For the latter type clips were ground welded to the columns to take the anchor bolts so that the columns could be held in position without waiting for the welding of shafts to the base slabs.

The beams were detailed with a connecting angle welded to the top flange at each end so as to maintain an accurate overall length and to insure the proper spacing of the columns to which they connect. A seat angle was welded on the columns to take the reaction from these beams and after the beams were placed the beams were welded to the seat angle and to the top connecting angle welded to the column, thereby making a stiff connection.

The bottom chord struts between the trusses were detailed with a small plate or bar, welded to the web of the strut at each end—this plate or bar being notched so that it would drop over the vertical leg of the angles constituting the bottom chord of the trusses, this holding it in place until field welding could be done.

The use of welded connections simplified these details as there were no gauge lines for holes and if necessary for a beam to be set off center it could readily be done using the same detail as if it had been required on the center of the column. In riveted work seat angles vary every time a gauge is changed, adding considerable to the complications of detailing.

As you have noticed, there are very few holes in this work except for the connection of what may be called "companion materials" and the only bolts used on the job for connecting steel to steel were for fastening purlins to trusses and window struts to columns.

In all, there are four buildings embraced in this operation. Building No. 1 is 60 ft. wide by 140 ft. long; has three floors and roof with an offset 20 ft. by 75 ft. of the same height as the main building. Building No. 2 is 60 ft. wide by 300 ft. long with a four story offset 20 ft. by 40 ft. Building No. 3 is 100 ft. wide by 460 ft. long, the two end bays of which compose the office building,—this Office Building being two stories high. Building No. 4 is 57 ft. wide by 132 ft. long and has a five ton crane runway.

With the exception of the offsets and the Office Building, the roof construction consists of trusses with monitors and channel purlins, the purlins of the Office Building being the J. & L. Junior Beams, as is also the case with the offset roofs. A walkway runs the full length of the inside of all monitors for the use of window cleaners. The walls are of brick and windows have steel sash—the trusses being from twenty feet to fifty-five feet above the ground level. Spandrel beams in general consist of beams with plates to carry brickwork and with window angles.

The total tonnage for all the buildings is approximately eight hundred seventy-five tons.

The instructions received at the time of undertaking this detailing were as follows. There was to be no punching of main material except crane girders for rail clips, window supports for sash and for purlins.

No bolts were to be used except where erection would be exceptionally difficult and for purlin connections.

No welding was to be done in the shop but all welding was to be done at the site.

No over-head welding was to be done.

All material to be ordered shipped direct from the Mill to site, unless punched, cut or milled. All punching, cutting and milling was to be done at the shop.

The details of beams framing to columns and girders were to be so made that they would automatically space the columns and could be easily clamped into position, regardless of any cutting variation.

Erection Diagrams were to show position of beams, etc., in their relation to column centers and floor lines.

These instructions were adhered to in the detailing of this work.

It is needless to say that placing a job of this size and character in a Drafting Room with the above instructions gave us some new problems to solve, as there were no leads available except a small amount of literature on Welded Structures and which described the various tests and the precedents set by riveted work—and while good, were by no means always applicable.

The natural tendency of structural draftsmen, by training and years of experience, is to visualize all connections and joints as riveted and it was necessary to overcome this tendency to a certain extent, for while the general conditions were similar to riveted work, the immediate requirements made it necessary to develop from these general conditions a welded job that would be satisfactory. From your observance this afternoon you may judge for your-

(Continued on page 97)

Practical Benefits of Accident Prevention*

RESULTS of one of the most effective joint efforts ever undertaken by the management and employees of the Bethlehem Steel Corporation are announced in this issue of the Review,

A year ago Bethlehem inaugurated a plan to stimulate greater interest in accident prevention and to provide an incentive for it in a gold award accident prevention contest among the various subsidiaries of the corporation.

I want to congratulate the employees and express the thanks and appreciation of the management for the remarkable improvement which has been made in our safety record in the last twelve months. A 25% reduction in accident severity as a result of this contest, in spite of increased operations, is a remarkable accomplishment.

This improvement, however, means a great deal more than merely establishing a proud record. Its greatest significance lies in two directions: First, in the economic saving to the company, to the employee, to his family, and to the community; second, in the habit of safe practice which such a record demands on the part of the individual.

The reduction in lost time accidents during 1928 represents not only a real conservation of life and health, but also a large saving in wages to Bethlehem employees, Add to that the reduction in cost of compensation and treatment of injured employees and the elimination of other costly wastes due to accidents and you get some idea of its economic importance.

Our task for the future is to make these practical benefits of lasting value, to fortify them by that habit of safety which comes only with persistent, well-organized effort every day in the year. The record of 1928 indicates that safe practices on the part of individual employees are becoming just as much a part of our operations as quality in our products. As a matter of fact, experience shows that efficient production and a good safety record usually go hand in hand.

In order to consolidate the gains we have made in 1928 and as a further encouragement to the management and employees, Bethlehem will conduct a gold award accident prevention contest in 1929. No one can review last year's results without confidence that Bethlehem employees will even better that remarkable achievement.

E. G. Grace

President

* Reprinted from the Bethlehem Review, January, 1929.

DETAILING OF WELDED STEEL BUILDINGS

(Continued from page 95)

selves how close we have come to carrying out this work properly.

The first actual work done in the Drawing Room was the ordering of main material—the major problem here being to decide whether the material should be ordered shipped to the Shop or direct to the site.

In writing the Order Bill the material was noted on the margin as to where it was to go and an item number was assigned to all material for identification, this item number being painted on all places marked as "shipped to the site," as this was the only readily available means of identification that could be used. There was a further use for this item number, which will be explained later.

In preparing the details, the fact that all welding was to be done at the site made it necessary to devise a system whereby all members of any particular piece could be identified and assembled. This was no small task, as can be gathered from the fact that the number of pieces to be handled was about twenty-six thousand and which varied from bars 2"x¼"x3" up to 24" beams 55 feet long.

Except for the trusses, all details were made on sketch sheets measuring 12"x24" and the component parts of each piece, be it a beam, column or truss, that was fabricated in the Shop was given an assembly mark, which mark was followed by the sheet or drawing number that was used as a shipping mark and listed alongside of the detailed sketch as Shop material, and the parts that had been shipped direct from the Mill were listed as "Field material" and carried the item numbers previously mentioned as appearing on the Mill orders. In this way it was easy for the Drafting Room, Shop and the Field man to tell at a glance from the detail drawings from what source the material would come.

The types of details used were seat angles and top clips, so far as possible, and where this was not sufficient a bar was welded to the end of the beam, which in turn was welded to the supporting member, making what in riveted work would be called a "web hitch." Where two beams of the same depth framed together, the web of the connecting beam had a bar welded to the web wihch in turn was welded to the web of the header beam and a bar was welded to bottom flange of main beams, extending out about two inches, for a landing seat—but where the header beam was deeper a seat angle was welded at the proper height. Spandrel sections and other light compound members were fastened together with tack welds, about 12" centers—these tack welds being about one inch long.

The detailing of the trusses on this work required considerable study as the chords were composed of two angles and both angles must take their share of all stresses. To do this, the web members had to be connected to both angles to properly distribute their load. Gusset plates were used only at the heels of the trusses and a small reinforcing plate was used at the peak. Clips for connecting purlins were welded to the rafters,—the outstanding legs of these clips being punched to receive purlins. The knee braces were punched with one hole at each end to receive drift pins for lining up the structure. Continuity for floor beams and purlins was obtained by continuity plates or bars on the top flanges over supporting members and welding in of bottom flanges to the supporting members to take the corresponding compression.

In specifying the welding, ¼" fillets were specified on all material ¼" thick and 5/16" fillets were used elsewhere with a few exceptions where heavier welds were required.

Great care was taken to properly distribute the welds over the connections so as to insure rigidity to the welded connection when completed.

In assembling the trusses the bottom chords and rafters were assembled and welded separately—these chords and rafters being afterwards put together in jigs so as to be held in proper position, after which the web members were put in place and the entire truss, including monitor frame, welded up into one piece. When this was done, the truss was taken off the welding skids and placed to one side until the time came to put it in the building.

In giving dimensions for these trusses, all dimensions were given to the backs of angles instead of to gauge lines as is customary on riveted work, the reason being that this gave the fitter a definite point to which to work and in the assembly, clamps were used for holding the material together preparatory to welding—and there was developed great ingenuity, as in spite of all efforts, many details were found that would be difficult to hold with the ordinary commercial clamp that is available in the market.

Items of Interest

David M. Petty, an active member of the A. I. & S. E. E. and a Past President of this organization, has been promoted to Superintendent of Service at the Lehigh Plant of the Bethlehem Steel Co., Bethlehem, Pa.

Mr. Petty after graduation at Lehigh University entered the service of the Bethlehem Steel Co., some fifteen years ago, as an employee of the electric department, later becoming the Superintendent of this department. He enjoys a national reputation as an Electrical Engineer in Steel Mill practices and has contributed to the Electrical Art with many valuable treatises and papers. Mr. Petty's friends who are legion in the Steel Industry, are congratulating him in his new capacity.

W. H. Ramage, an active member of the A. I. & S. E. E., formerly Vice President of the Valley Mould & Iron Corporation, has just recently been

elected to the Presidency of this organization, succeeding Mr. John E. Perry, who was elected Chairman of the Board of Directors. Mr. Ramage has been with the Valley Mould & Iron Company since 1918. For several years previous to this he was Chief Engineer of the Brier Hill Steel Co., at Youngstown, Ohio. "Bill" as he is known in Steel Mill circles has the best wishes of the membership in the Association and his countless friends for a successful administration in his new capacity.

Mr. F. L. Estep, one of the active members of this Association and one of the firm members of the Perin & Marshall Co., at New York, has just recently returned from Europe where he made an extensive study of rolling mill practices in Germany, France and Spain.

Mr. Thomas Peebles, connected with the Hagan Corporation, has just returned from England and other foreign countries where he investigated combustion control systems in use in industrial plants.

Mr. H. F. Slack has accepted a position with the Bussmann Mfg. Co. as Sales Manager, Pittsburgh District. Mr. Slack is an associate member of the A. I. & S. E. E.

Mr. Gordon W. First has accepted a position with the Pittsburgh Division of the Clark Controller Co. Mr. First will call on the Industrials in the Pittsburgh District.

Mr. A. J. Freund, Sales Engineer Electric Controller & Mfg. Co., with headquarters at Pittsburgh, Pa., has been transferred to the Chicago office of this company.

Mr. Max Rubenstein has been transferred from the Philadelphia Sales Office of the Standard Underground Cable Co., Division of General Cable Corporation, to the General Offices of the company in Pittsburgh, where he will devote his time to the promoting of sales of Cable Accessories. Mr. Rubenstein has been with the Philadelphia Sales Office of the Standard Underground Cable Co. for many years, and is well known among the electrical and allied industries of eastern Pennsylvania, New Jersey and Delaware.

Mr. Paul Jones, District Manager of the Cutler Hammer Manufacturing Company, Pittsburgh, Pa., has been transferred to New York. Mr. Jones will assume the duties of Manager, New York District, Cutler Hammer Mfg. Co. This district comprises Eastern New York State, Western New Jersey, Connecticut and Eastern Canada. Mr. Jones after graduation at the Ohio State University entered the Cutler Hammer Mfg. Company organization in 1915 at Milwaukee. Three years later, he was transferred to the Steel Mill Division at Pittsburgh, Pa., later becoming District Manager of this office. Paul Jones is a member of the Association of Iron and Steel Electrical Engineers and has a host of friends in the Steel Industry throughout the United States. The Membership of the A. I. & S. E. E. wishes to extend their heartiest congratulations and best wishes for a prosperous career in his new capacity.

Mr. Thomas H. Towle, formerly in charge of the Steel Division of The Cutler Hammer Mfg. Co., at Pittsburgh, Pa., has been appointed Manager of the Pittsburgh District. Mr. Towle, after graduation from Cornell University, entered the employ of The Cutler Hammer Company at Milwaukee in 1919, later being transferred to the Pittsburgh Office. Mr. Towle is a member of the A. I. & S. E. E., and enjoys a wide acquaintanceship in the Steel Industry. His many friends as well as the A. I. & S. E. E., wish him well in his new undertaking.

Mr. W. C. Anderson, formerly with the Eastern Branch of the Trumbull Electric Mfg. Company will now be located in the Pittsburgh District, succeeding Mr. F. M. Buckley, who has been transferred to the New York Branch.

LARGE FOOT BRIDGE CONSTRUCTED BY WELDING

A foot bridge 846 feet long, for the convenience of employes of the General Electric Company's plant at Schenectady, was recently constructed by electric arc welding. This bridge, containing 105 tons of steel, extends over the Delaware & Hudson Railroad tracks to a nearby hillside.

Beam and girder construction is used. A total of 20 spans is involved, varying in length from 20 to 60 feet. The bridge rests on towers and "bents" (or posts) principally the latter, three towers being used at the highest points for bracing purposes. A total of 14 bents supports the remainder of the structure.

Two sizes of girders are employed, both Bethlehem shapes: one is 22", 58 pounds per foot, and the other is 30", 110 pounds per foot. These form the bridge stringers. The columns are 10/8 Bethlehem H sections, 33½ pounds per foot, varying height from six to 37 feet—an 8% grade. The floor beams are 8-inch Bethlehem I-beams, 17½ pounds per foot, spaced every 10 feet on centers. Floor planks are laid on wood stringers. Bracing angles for the bents vary in size, but most of them are 4x3x¼ inch stock.

Near the ground the bridge makes a turn almost at right angles. Near the upper end is located a gate house. From the lower ramp to the gate house the distance is 571 feet. The gate house is 20 feet in length, and the distance from the gates to the upper end is 255 feet.

HERRINGBONE GEAR REDUCING UNITS

Gears and Forgings, Inc., have recently installed a Herringbone Gear Reduction drive in the plant of the Timken Roller Bearing Company at Canton, Ohio. This unit represents a step forward—for it demonstrates the practicability of roller bearings on equipment of this type. It is completely equipped with Tapered Roller Bearings on both pinion and gear shafts.

It was designed and built by Gears and Forgings, Inc., to transmit power from a 1500 horse power (4,000 horse power peak loads) A. C. motor at 360 R.P.M. to two stands of 28" bar mills. It is interesting to note that two eight foot fly wheels each weighing 16,000 pounds are mounted on the pinion shaft to take care of the peak loads resulting from the mills.

Gears and Forgings, Inc., are at present building a 1000 horse power Herringbone Reduction Unit for a seamless tube piercing mill for Timken's new tube mill and a Herringbone Gear tandem sheet mill drive for the new Tin Mill of The Columbia Steel Co., Pittsburgh, California.

NEW FAN COOLED MOTOR

Leaflet L-20384, describing a new fan-cooled, totally enclosed squirrel cage induction motor, has recently been published by the Westinghouse Electric and Manufacturing Company.

This motor is designed for use in locations where the service conditions are too severe to permit the use of a standard open motor. Foundries, cement mills, coke plants, flour mills, and machine shops, are industries where this type of motor finds frequent application.

An important feature of this line of motors is that their size is approximately the same as that of a standard open motor of equivalent rating.

In construction, these motors are almost identical to that of the standard open motor. The stators differ only in that the ends of the windings are enclosed in sturdy, sheet metal, protective housings. The rotors are identical except for the addition of a machined steel collar mounted on either end of the shaft. These collars serve as supports for the external cooling fans. The external cooling fans draw outside air in through the brackets at either end and, after directing it over the entire outside surface of the protective housing, discharge it through the middle section. This construction makes possible the use of short, direct air passages which allow ready passage for great volumes of cooling air. The clean air sealed in the interior of the motor is kept in circulation by blowers on the ends of the rotor, and transfers the heat generated in the windings to the protective housing, where it is dissipated by the outside cooling air. In this way, any injurious material in the outside air, never reaches the interior of the motor.

Fan-cooled, totally enclosed motors are supplied, equipped with standard ball bearings. This construction is essential due to the minimum amount of end-play allowable. These motors use the same control as any standard squirrel cage induction motor and may either be started at reduced voltage by the auto-starter, or across-full line voltage by the Line-starter.

THE TIMKEN STEEL AND TUBE CO.'S NEW PLANT

The Timken Steel and Tube Company has put into effect an expansion program for the coming year that will necessitate expenditures in the neighborhood of $1,000,000. A tract of land 200 acres in extent has been purchased, which extends 2 miles west of the Company's present holdings. This will provide room for future expansion of the plant facilities on the present basis of straight line production.

Work has already been started on the first unit, a tube mill, which will be housed in a building 320 feet wide by 420 feet long. It is being erected at a cost of over half a million dollars for building and equipment. This mill will be completed and put into operation by April 1. Other extensions to the production facilities of the Company will be made later.

MORGAN ENGINEERING CO BULLETIN

The Morgan Engineering Co., at Alliance, Ohio, has just recently issued a handsome and attractive bulletin, known as No. 23.

This bulletin calls attention to a few of the prominent features of Morgan Ladle Cranes. Write The Morgan Engineering Co., Alliance, Ohio, for details.

WARRIOR RIVER TOWBOAT READY FOR SERVICE

The Diesel-electric towboat which has been under construction for the Tennessee Coal, Iron & Railroad Company was given her trials recently and left January 22 for the Warrior River in Alabama where she will be put in service. The boat was built by the American Bridge Company at Clarion, Pa., and was outfitted by the Carnegie Steel Company of Pittsburgh. From Clarion her route is down the Monongahela River to Pittsburgh, then down the Ohio River to the Mississippi, then down to the Gulf and up the Warrior River to the Port of Birmingham where her owners are located.

The Tennessee Coal, Iron & Railroad Company has several steam boats of the stern paddle wheel type in operation. The new boat, of the tunnel stern, twin-screw wheel type, will be propelled by Diesel-electric drive in order to obtain higher efficiency and better maneuvering qualities. Electric drive is expected to be particularly advantageous in this service, as the Warrior River is a tortuous one having many sharp bends, and is relatively shallow with swift currents. The length of "tow" is limited to seven barges by reason of the bends in the river. All the barges except one are pushed ahead by the towboat, the remaining barge being towed alongside.

The boat is electrically equipped excepting only the cooking and heating, steam for the latter being provided by a small donkey boiler. The power plant consists of two 550-horsepower Diesel engines manufactured by the New London Ship & Engine Company, each direct connected to a 335-kilowatt, 250-volt, 250-r.p.m., direct-current generator. Each propeller is driven by a shunt-wound, double motor rated 400 horsepower, 140-r.p.m., 250 volts. All the electric equipment was furnished by the General Electric Company.

Power for auxiliaries and lighting, as well as for exciting the main generators and propelling motors, is furnished by two 40-kilowatt, 120-volt, compound-wound, direct-current, auxiliary generators. These are driven by the main engines and are mounted directly on shaft extensions of the main generators. Variable voltage (Ward Leonard) control is used, arranged for operation either from the pilot house or the engine room.

ALLIS-CHALMERS ANNOUNCES ENLARGED TEXROPE STOCK

On account of the increasing demand for immediate shipment of transmission machinery, it has been necessary for the Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin, to enlarge their stock of Texrope drives up to 50 HP. In 1927 an announcement was made that Texrope drives from 2 HP up to 15 HP were being carried in stock ready for immediate shipment. This was received so favorably that at the present time this stock of Texrope drives has been increased to include all the popular motor speeds and ratings up to 50 HP with a large choice of driven speeds in a range of ratios from 1:1 up to 7:1.

A catalog has been prepared to make selection of a suitable Texrope drive a simple matter.

—MEETINGS—

PHILADELPHIA SECTION

Saturday, March 2, 1929 — Engineers Club, Philadelphia, Pa.

"THE INCORPORATION OF SAFETY INTO ELECTRICAL STATION DESIGN," V. R. Bacon and H. L. Unland, Engineers, United Engineers and Constructors, Inc., Philadelphia, Pa.

PITTSBURGH DISTRICT SECTION

Saturday, March 2, 1929 — Wm. Penn Hotel, Pittsburgh, Pa.

Materials Handling Symposium

ELECTRIC TRUCKS AND TRACTORS, Baker Raulang Co.; GAS-ELECTRIC LOCOMOTIVES, Geo. D. Whitcomb Co.; EXCAVATION, Harnischfeger Corp.; ELECTRIC TELPHERAGE SYSTEMS, J. H. Overpeck Co.

Dinner 6:30 P. M. — Technical Sessions, 2:30 P. M. and 8.00 P. M.

Saturday, March 23, 1929 — Wm. Penn Hotel, Pittsburgh, Pa.

"SHORT CIRCUIT STUDY APPLIED TO A STEEL PLANT POWER TRANSMISSION SYSTEM," by R. M. Hussey, Electrical Superintendent, Jones & Laughlin Steel Corp., Aliquippa, Pa.

CLEVELAND DISTRICT SECTION

Friday, February 15, 1929 — (TIME AND PLAN OF MEETING IN LATER NOTICE)

"AIR CLEANING IN THE STEEL INDUSTRY," by J. H. Milliken, Vice President, Reed Air Filter Co., Louisville, Kentucky.

CHICAGO DISTRICT SECTION

MARCH

Inspection Trip to Crawford Station of the Commonwealth Edison Company.

Paper by Mr. Schuchardt, Chief Electrical Engineer, Commonwealth Edison Company, on "The Interchange of Power Between Central Station and Steel Plants," Dinner furnished by Commonwealth Edison Company.

MARCH

Combustion Engineering Division Meeting. "Recuperative Soaking Pits," by G. R. McDermott, Vice President Chapman-Stein Co., Mt. Vernon, O.

APRIL

"Application of Roller Bearings to Main Roll Drives, and Other Industrial Applications of Particular Interest to Steel Mill Engineers," by Mr. F. Waldorf, of the Timken Roller Bearing Company.

MAY

Golf Tournament—All District Sections Invited.